Volume 45 Number 4

ANNALS

OF

The Entomological Society of America

DECEMBER, 1952

HERBERT OSBORN, *Editor Emeritus*

EDITORIAL BOARD

MAURICE T. JAMES, Managing Editor,
PULLMAN, WASHINGTON
A. GLENN RICHARDS, Assistant Editor,
ST. PAUL, MINNESOTA

1952	1953	1954
A. B. KLOTS, NEW YORK, N. Y.	G. S. WALLEY, OTTAWA, ONTARIO.	A. GLENN RICHARDS, ST. PAUL, MINN.
P. O. RITCHER, RALEIGH, N. C.	A. B. GURNEY, WASHINGTON, D. C.	J. N. BELKIN, LOS ANGELES, CALIF.
J. N. KNULL, COLUMBUS, OHIO.	F. M. CARPENTER, CAMBRIDGE, MASS.	ALBERT MILLER, NEW ORLEANS, LA.

PUBLISHED QUARTERLY BY THE SOCIETY
COLUMBUS, OHIO

Entered as second-class matter April 11, 1908, at the Post Office at Columbus, Ohio, under the Act of Congress of March 3, 1879. Subject to rate of postage provided for in Paragraph 4, Section 538, P. L. & R., authorized September 16, 1940.

The Entomological Society of America

Founded 1906

OFFICERS, 1952

President

E. G. LINSLEY . . . . . Berkeley, Calif.

First Vice-President

HERBERT H. ROSS . . . . . Urbana, Illinois

Second Vice-President

CURTIS W. SABROSKY . . . . . Washington, D. C.

Secretary

A. C. HODSON . . . . . St. Paul, Minn.

Treasurer

S. W. FROST . . . . . State College, Penn.

Managing Editor Annals

MAURICE T. JAMES . . . . . Pullman, Wash.

Executive Committee

1952	1953	1954
MELVILLE H. HATCH	C. F. W. MUESEBECK	RAYMOND H. BEAMER
W. H. ANDERSON		ARTHUR C. COLE

Thomas Say Foundation

Editor—J. J. DAVIS; *Treasurer*—S. W. FROST

1952	1953
R. S. USINGER	R. G. SCHMIEDER
C. D. MICHENER	T. H. HUBBELL

ANNALS
OF
The Entomological Society of America

Volume 45 DECEMBER, 1952 No. 4

NOTES ON THE PHLEBOTOMUS OF PANAMA

IX. Descriptions of Seven New Species[1]

G. B. FAIRCHILD AND MARSHALL HERTIG
Gorgas Memorial Laboratory
Panama, R. de P.

Collections of *Phlebotomus* sandflies in Panama now indicate the presence of 57 species within the boundaries of the Republic. Of these, 23 are species previously described from elsewhere, 6 have been described previously by us from Panama and 28 appear to be new. Of these last, we have selected the following 7 for description mainly because they are represented by reasonably abundant material and because we are fairly certain of the association of the sexes. The remaining 21 species will be described as good series become available and as we satisfy ourselves as to the association of the sexes. Types of the present species, as well as those previously described by us, will be deposited in the U. S. National Museum.

Phlebotomus dysponetus sp. nov.

Plate I, figs. 1–8

Male.—Wing length 1.89 to 2.07 mm. A medium sized rather dark sandfly, the mesonotum, pleura, coxae and dorsum of abdomen rather heavily infuscated. Abdominal setae erect or semi-erect, not scale-like. Post-spiracular setae about 14, lower mesanepisternal setae about 7. Proboscis slightly less than head height. Basal antennal segments and palpi as figured. Newstead's scales long, scattered over the middle third of third palpal segment. Ascoids as long as their respective segments, simple, as figured, paired on all but the terminal segment of antennae. Terminal segments not abruptly shorter than preceding ones. Wing venation as figured. Cibarium without horizontal teeth and lacking the heavily sclerotized structures below the tooth row found in female. Genitalia as figured, the genital pump large, the filaments hardly twice as long as pump, their tips dilated, as figured.

[1]Cost of publication is paid by the Gorgas Memorial Laboratory.

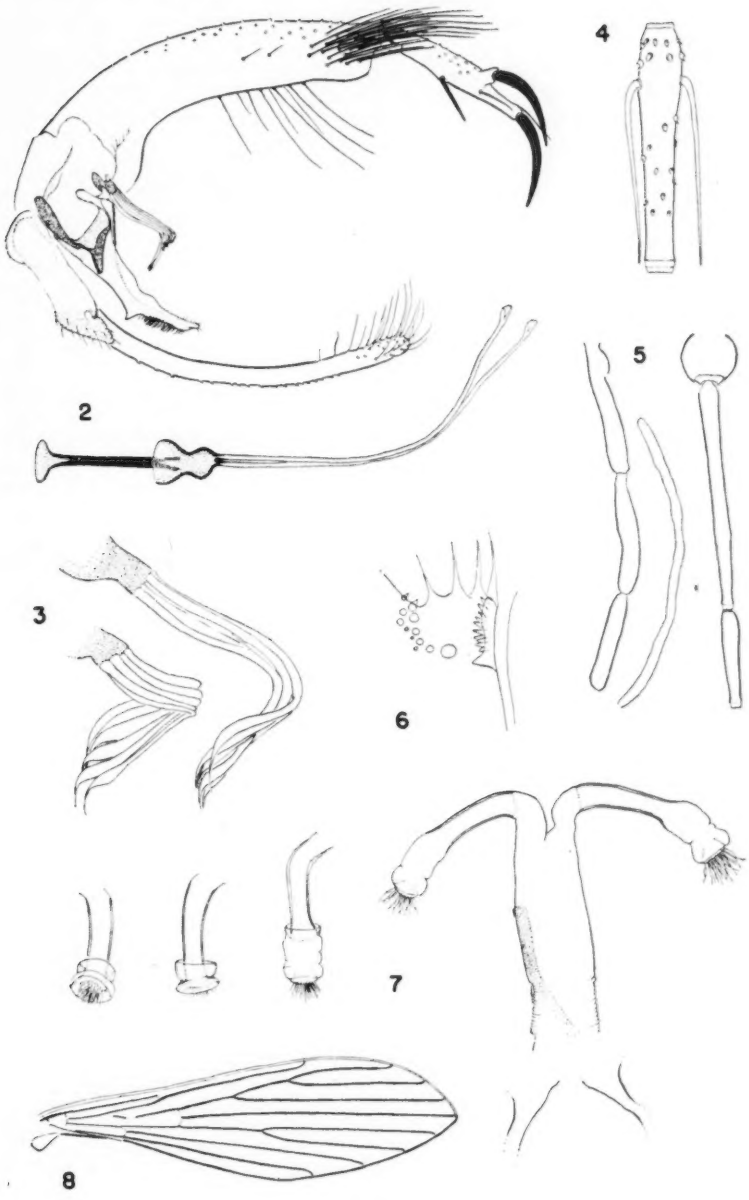
Female.—Wing length 1.83 to 2.07 mm. Externally similar to the male. Mesanepisternal setae fewer, ligulate and scale-like. No setae on lateral aspect of eighth tergite. Proboscis equal to or slightly exceeding head height. Basal antennal segments and palpi as in male, the antennal segments slightly shorter, the palpi slightly longer than in that sex. Ascoids as in male. Cibarium as in *acanthobasis* n. sp. Spermathecae as figured. Pharynx rather broad and well sclerotized, its posterior end with numerous fine transverse ridges which appear to be minutely denticulate. Wing as in male, clothed with hairs and a few ligulate scales at extreme base.

Holotype male, slide 2046, Juan Mina, Chagres river between Gamboa and Madden Dam, Canal Zone, 13 December, 1949, taken in an automatic fan type light-trap. H. Trapido coll. *Allotype* female, slide 2012, same locality, 15 December, 1949, taken in a hollow tree containing bats. M. Hertig coll. *Paratypes,* 40 males and 47 females mounted on slides from the following localities: Juan Mina, Chagres river region, C. Z., 1940, probably at light; 16 April, 1944, in hollow tree with bats; 3 May, 1944, same habitat; 14 Nov., 1949, in light trap; 15 Dec., 1949, in hollow tree with bats; 13 Dec., 1949, in light trap; 20 Dec., 1949, in light trap; 27 Oct., 1949, in light trap; 10 Nov., 1950, in light trap; 11 July, 1951, in Shannon trap at light; Darien, R. P., no data, probably El Real, at light, 1940; Old Panama, in holes and crevices in ruins, 27 Aug., 1943, 14 Dec., 1946, 3 June, 1944, 4 June, 1945, 7 Oct., 1947; Sta. Rosa, Chagres river region, in hollow tree, 26 May, 1945; Chiva Chiva, C. Z., in light trap, Oct., 1948; Madden Dam, C. Z., in light trap, 17 Nov., 1948; Tocumen airport, R. P., in light trap, 21 Jan., 1949; Nutivi, upper Rio Cricamola, Bocas Province, R. P., in pigsty, 15 June, 1949; Pacora, R. P., in animal burrow, 13 Aug., 1950; Suerre, Costa Rica, in buttresses, 29 April, 1951; Loma Borracha, C. Z., in light trap, Oct., 1951; Charco el Toro, Rio Maje, Panama Prov., R. P., in hollow tree, 23 March, 1950. In addition we have 538 unmounted specimens from the above localities and a number of additional localities in the Canal Zone, Panama and Costa Rica.

The species has been taken in all months of the year, though predominantly in the rainy season from May through December. Aside from one very large catch of 411 specimens from an animal burrow, most of our material has come from mosquito light traps or Shannon traps at light (123). Burrows have yielded specimens three times for a total of 447 specimens, holes and crevices in ruined walls 32 specimens, hollow trees with bats 18 specimens, and scattered examples from

EXPLANATION OF PLATE I

Phlebotomus dysponetus n. sp. FIG. 1, male genitalia, holotype, × 135. FIG. 2, genital pump and filaments, × 135. FIG. 3, basal tufts of coxite drawn in phenol, × 270. FIG. 4, antennal segment IV of male, × 270. FIG. 5, basal antennal segments and palpi of male, × 135. FIG. 6, cibarial teeth of female, the right side is folded so that the erect teeth are seen in profile, × 604.5. FIG. 7, spermathecae, the right-hand figure shows the heads fully expanded, the three figures to the left show various degrees of contraction, × 270. FIG. 8, wing of male holotype, × 32.


4
2
5
3
6
7
8

buttresses, hollow trees, and a house. A pigsty yielded 38 specimens, some said to be biting the pigs, which is the only host record we have for the species.

The species has been taken several times in heavy forest on the Atlantic side of the isthmus, but the bulk of the material comes from relatively dry gallery forest or second-growth scrub on the Pacific side. We have not taken it at any elevation in the mountains nor at Almirante in the very heavy Atlantic rain forest, where considerable collecting has been done. Its absence from horse baited mosquito traps is also significant, as these have been used extensively in localities where the species is taken fairly frequently at light.

P. dysponetus is closely related to *acanthobasis* n. sp. and to *triacanthus* Mang., *trispinosus* Mang., *equatorialis* Mang., and *choti* Floch and Abonnenc, for which Mangabeira (1942) proposed the subgenus *Pressatia*. It differs from all these in the slender parameres, lack of tuft of fine setae above the modified spines on the base of the coxite and in the greater inflation of the tips of the genital filaments. Mangabeira (1942a) has described the early stages and the female of *P. triacanthus*. *P. dysponetus* differs in this sex in details of the cibarium and spermathecae, though the differences are slight. The females of *P. choti* F. & A., described and figured by Floch and Abonnenc (1941) are also exceedingly similar. Both authors appear to have figured the spermathecae in a retracted condition, such as is usually seen in balsam mounts, with the sclerotized ducts telescoped into the tenuous heads.

Phlebotomus acanthobasis sp. nov.

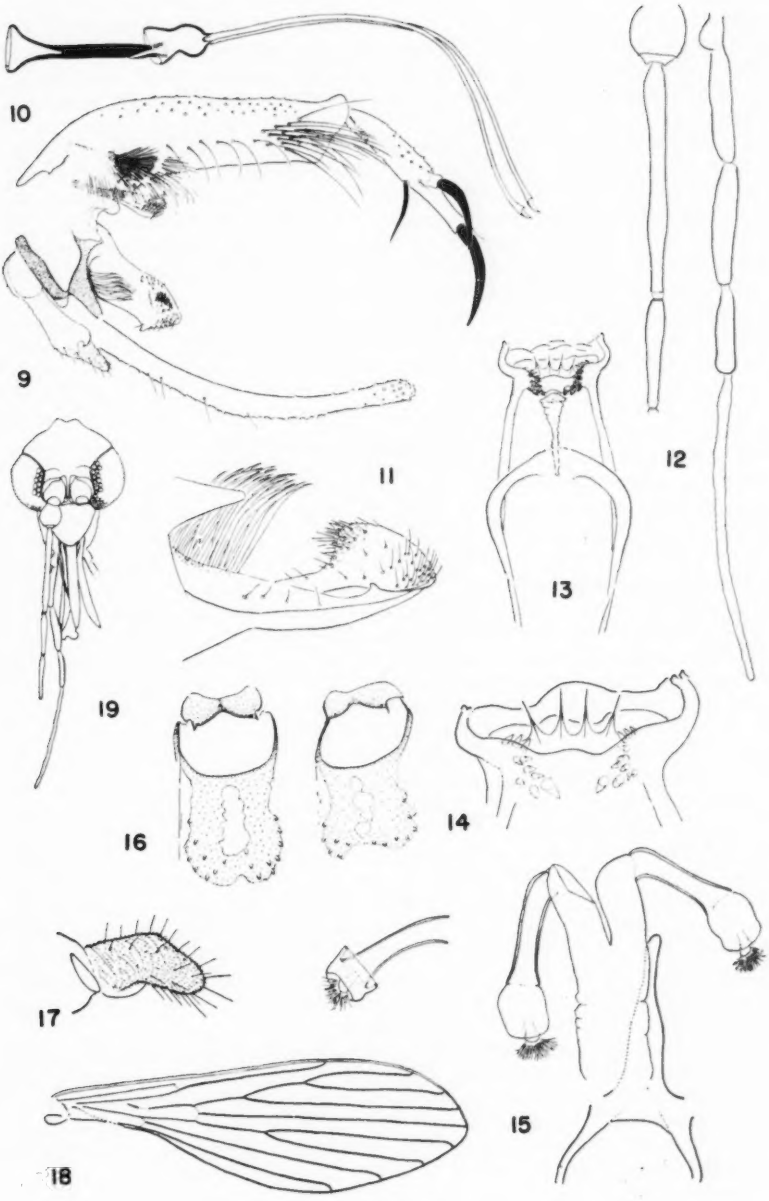
Plate II, figs. 9–19

Male.—Wing length 1.89 to 2.08 mm. A medium sized somewhat dusky sandfly, the mesonotum, pleura, coxae and abdominal sclerites rather evenly infuscated. Abdominal setae erect or semi-erect, not scale-like. Post-spiracular setae about 14, lower mesanepisternal setae about 3, the latter ligulate. Proboscis slightly less than head height. Basal antennal segments and palpi as in *P. dysponetus* n. sp. Newstead's scales scattered over middle third of third palpal segment. Ascoids simple, reaching to or beyond the ends of their respective segments, paired on all but the terminal segment. Wing venation as figured. Cibarium apparently without horizontal teeth, but with numerous reduced fine vertical teeth in the same position as the vertical teeth of the female. Pharynx slender, well sclerotized, unarmed. Genitalia as figured, notable for the numerous blade-like spines arising

---

EXPLANATION OF PLATE II

Phlebotomus acanthobasis n. sp. FIG. 9, male genitalia, holotype, × 135. FIG. 10, pump and genital filaments of another specimen, × 135. FIG. 11, ventral view of paramere and tip of aedeagus of another specimen, × 270. FIG. 12, basal antennal segments and palpi of female, × 135. FIG. 13, female cibarium, × 270; FIG. 14, same specimen, × 604.5. FIG. 15, spermathecae, fully expanded and, to the left, a single head contracted, × 270. FIG. 16, first and second sternites, male left, female right, × 135. FIG. 17, female cercus, × 135. FIG. 18, wing, male, × 32. FIG. 19, frontal view of female head, × 49.


10
9
11
12
13
19
16
14
17
15
18

on the ventral border of the inner aspect of the parameres. Basal tuft of hooked modified setae on coxite essentially as in ***dysponetus***, but obscured by the dense tuft of long fine setae arising from a rather long finger-like protuberance above it. Genital pump large, the rather heavy filaments slightly more than twice as long as the pump, as figured.

Female.—Wing length 1.81 to 2.14 mm. Externally similar to the male. No setae on lateral aspect of eighth tergite. Proboscis equal to or slightly exceeding head height. Basal antennal segments and palpi as figured. Newstead's scales and ascoids as in male. Cibarium and spermathecae as figured. Pharynx unarmed, somewhat broader than in male, its posterior end finely ridged. Wing as in male, clothed with hairs and a few ligulate scales at base.

Holotype male, slide 2019, Gatuncillo, Chagres river between Gamboa, C. Z., and Madden Dam, 15 December, 1949. Taken in a hollow tree containing bats. M. Hertig coll. *Allotype* female, slide 2370, La Victoria, Cerro Jefe, nr. Pacora, Panama Prov., R. P., 29 August, 1950. Taken at light in a Shannon trap. Hertig & Galindo coll. *Paratypes*, 22 males and 32 females mounted on slides from the following localities: Juan Mina, Chagres river between Gamboa and Madden Dam, Canal Zone, 16 April, 3 and 30 May, 1944, in hollow tree with bats, 11 July, 1951, in hollow tree with bats and in Shannon trap at light; Chorrera, R. P., 18 March and 7 April, 1944, in animal burrow; Cerro Campana, Panama Prov., R. P., 18 Jan., 1947, in hollow tree with *Didelphis* opossum, 24 Aug., 1950, in Shannon trap at light; Upper Rio Pequeni, R. P., 26 March, 1949, probably in animal burrow; Nutivi, upper Rio Cricamola, Bocas del Toro Prov., R. P , 15 June, 1949, in pigsty; Palenque, Colon Prov., R. P., 14, 15 Sept., 1949, in hollow tree and in buttress; Rio del Medio, nr. Rio Gatun, C. Z., 14 Oct., 1949, in buttress; Gatuncillo, Chagres river above Gamboa, C. Z., 15 Dec., 1949, in hollow tree with bats; Charco el Toro, Rio Maje, Panama Prov., R. P., 22, 26 March, 1950, in hollow tree and in buttress; La Victoria, Cerro Jefe, nr. Pacora, R. P., 29 Aug., 1950, Shannon trap at light, 4 June, 1951, in automatic light trap; Almirante, Bocas del Toro, R. P., 16 May, 1951, in buttress, 5 July, 3 Aug., 1951, and 7 Jan., 1952, in Shannon trap at light; Cruces trail, C. Z., forest reserve, 10 and 25 Aug., 1951, in buttresses and in Shannon trap at light; Arraijan, R. P., 14 Aug., 1951, in automatic light trap; Gatun, C. Z., 29 Aug., 1951, in light trap; Mojinga swamp, nr. Ft. Sherman, C. Z., 5 Sept., 1951, in light trap; Madden Dam, C. Z., 21 Sept., 1951, in light trap; Loma Borracho, C. Z., 17 Oct., 1951, in light trap; Wauchope, Limon Prov., Costa Rica, 9 Aug., 1951, in buttress; Suerre, Guapiles, Costa Rica, 29 April, 1951, in buttress.

In addition to the above, we have 49 males and 18 females from the above localities and from Turrialba, Costa Rica, 11 and 12 Feb., 1952, at light, which have been identified and stored unmounted. The species has been taken in every month of the year, but the numbers are too small to show seasonal trends if such exist. We have taken the species 20 times attracted to light, either in a Shannon trap or in automatic light traps, but usually only one or two specimens at a time. It has been taken 11 times in buttresses, 6 times in animal

burrows, 5 times in hollow trees containing bats, 3 times in hollow trees without bats and once in a pigsty. Only twice have fair numbers been taken at one place, in an animal burrow in Costa Rica and in a bat tree in the Canal Zone; otherwise the species is comparatively scarce. The localities at which the species has been taken include areas of heavy forest on the Atlantic slope as well as comparatively dry scrub forest on the Pacific slope and up to about 2000 ft. elevation in the mountains. The Costa Rican localities are all on the Atlantic slope.

P. acanthobasis is related to *P. dysponetus* n. sp. *triacanthus* Mang., *trispinosus* Mang. and *choti* F. and A., differing from all these in the row of blade like spines on the base of the paramere below. The female differs from *dysponetus* only in the smaller terminal knob and longer individual ducts of the spermathecae. The cibarium is indistinguishable from that of *dysponetus*, but both species appear to differ from *triacanthus* and *choti* in having larger and heavier vertical teeth in the cibarium.

Phlebotomus aclydiferus sp. nov.

Plate III, figs. 20–30; plate VI, figs. 61–62

Male.—Wing length 2.08–2.43 mm. A large dark sandfly, the mesonotum, pleura and legs all rather heavily infuscated. Abdominal setae erect or semi-erect, not scale like. Post-spiracular setae about 14, lower mesanepisternal setae about 2. Proboscis from tip of labium to base of maxillae a little shorter than head height from vertex to base of clypeus. Basal antennal segments and palpi as figured. Newstead's scales long, scattered along the distal two-thirds of third palpal segment. Ascoids similar to those of female, very long, with long posterior prolongations, paired on all flagellar segments except the last three. Terminal three segments not abruptly shortened, but segments progressively shortened from about segment XII. Wing as in female, though a little narrower. Cibarium and pharynx as in female, though teeth of former smaller and finer. Genitalia as figured. Genital filaments a little more than twice as long as pump, the latter slender, with small expansion of anterior end of plunger. The cerci, though smaller, are of same shape as those of female.

Female.—Wing length 2.16 to 2.64 mm. Similar in color and setal arrangement to the male. A few setae, about three, on lateral aspect of eighth tergite. Proboscis a little longer than head height. Basal antennal segments and palpi as figured, the palpi longer, antennal segments shorter than in male. Ascoids as figured, paired on all segments but the last two. Newstead's scales as in male. Cibarium, wing, spermathecae and cerci as figured. There are very fine denticles on the ridges of the pharynx. Wing veins clothed with slender setae, except at extreme base, where these are largely replaced by ligulate, square ended, striated scales.

Holotype male, slide 3489, Mojinga swamp, nr. Gatun, C. Z., 21 Aug., 1951. Taken in light trap. F. S. Blanton coll. *Allotype* female, slide 3359, Juan Mina, C. Z., 11 July, 1951. Taken between buttressed roots of a hollow tree with bats. Hertig, Galindo &

Hartmann colls. *Paratypes:* 24 males, 23 females from the following localities: Ft. San Lorenzo, C. Z., 24 Oct., 1943, in holes in ruins; Police station, Rio Pequeni, Madden Lake, C. Z., 23 June, 1944, in buttresses; San Antonio, Rio Pequeni, R. P., 25 Mar., 1949, in rock crevices near river; La Victoria, Cerro Jefe, nr. Pacora, R. P., 2000 ft. elev., 23 Jan., 1947, in animal burrow and rock crevices and 16 Dec., 1948, in buttresses or animal burrow; Rio Las Cascadas, Cerro Jefe, 26 Feb., 1948, at light; Puerto Pilon, Colon Prov., 2 Feb., 1947, in animal burrow; Juan Mina, C. Z., 20 Dec., 1949, in light trap and 11 July, 1951, in bat tree or buttress; Cerro Campana, Panama Prov., 24 Aug., 1950, at light; Puerto Armuelles, Chiriqui Prov., 9 June, 1951, at light; Cruces Trail, C. Z., 5 July, 1951, at light; Finca Nievecita, Almirante, Bocas del Toro Prov., 19 June, 1950, in buttress; Pacora, Panama Prov., 4 June, 1951, light trap; Mojinga swamp, Gatun, C. Z., 21 Aug. and 5 Sept., 1951, light trap. COSTA RICA: Guapiles, 17 June, 1950. MEXICO: Sta. Maria, Cintalapa, Chiapas, 11 April, 1951, Shannon trap at light.

In addition to the above 49 mounted specimens we have 138 males and 76 females unmounted from the above Panama localities and from Suerre, Turrialba and Pacurae in Costa Rica. We have taken the species in every month of the year save March and May, but it appears to be more abundant in the rainy season, from June through December. Most of our material has been taken attracted to light, either in a Shannon trap or automatic mosquito light trap. Twenty-two specimens were taken in animal burrows, 13 in buttresses and 10 in other habitats, including bat trees, crevices in rocks and holes in ruins. All but a few specimens have come from areas of heavy rain forest on the Atlantic slope of the continental divide or from elevations of 1500 ft. or more.

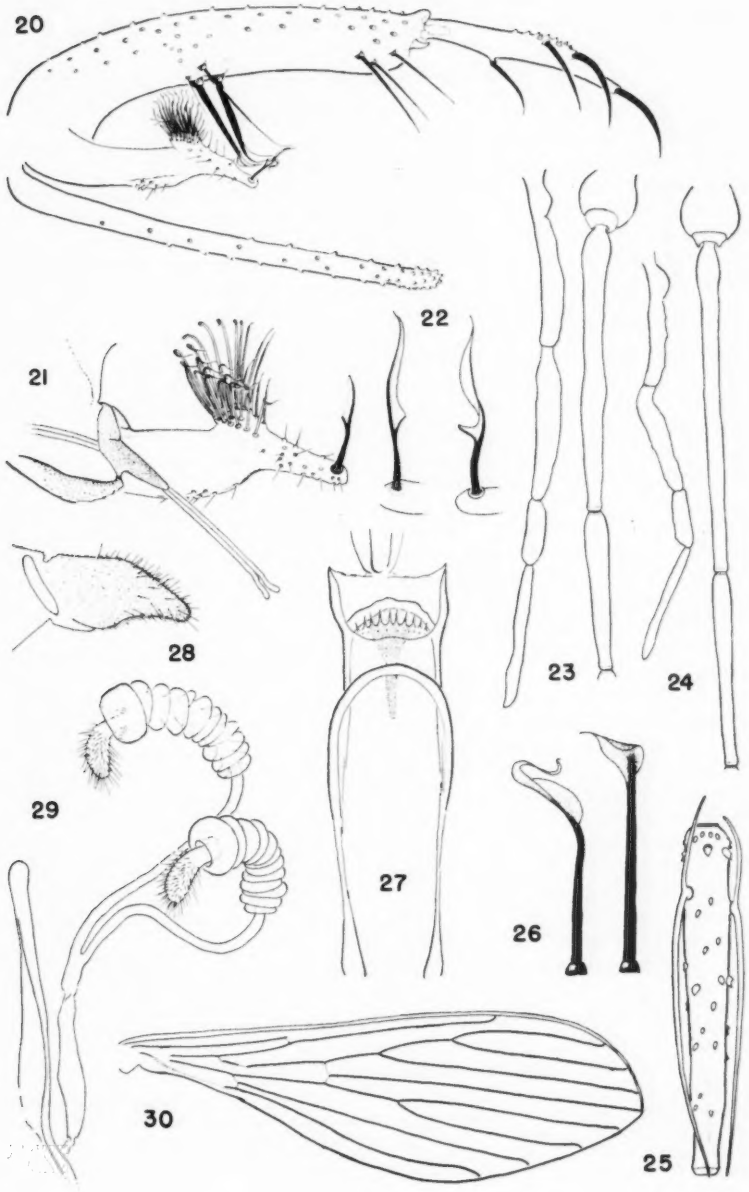
This species is not obviously related to any described Neotropical species, but comes nearest to such species as *P. dunhami* D. & C., *castanheirai* D. & C., and *campbelli* D. & C. in the structure of the male genitalia. The spermathecae and cibarium are of the same type found in *anduzei* Rozeb. and *apicalis* Floch & Abonnenc. These latter lack, however, the long proximal prolongations of the ascoids found in *aclydiferus*. *P. campbelli* D. & C. also has ascoids like *aclydiferus*, as an examination of the type in the U. S. National Museum shows.

There is some variation in certain structures. The spines at apex of coxite vary from two to four in number. In the material from Chiapas, Mexico, there is a very long seta on the outside of the coxite, reaching at least to the tip of the lateral lobes. In most Panama material, this seta is less developed. The parameres of the Mexican

---

EXPLANATION OF PLATE III

Phlebotomus aclydiferus n. sp. FIG. 20, male genitalia, paratype, × 135. FIG. 21, paramere and aedeagus of another specimen, × 200. FIG. 22, spine on tip of paramere, two different specimens, × 270. FIG. 23, basal antennal segments and palpi of female, × 135. FIG. 24, same of male, × 135. FIG. 25, antennal segment VII of female, × 270. FIG. 26, spines of bare of coxite, × 270. FIG. 29, female cibarium, × 270. FIG. 28, female cercus, × 135. FIG. 29, spermathecae, drawn in phenol, × 270. FIG. 30, female wing, × 32.


20
22
21
28
23
24
29
27
26
30
25

specimens differ in having the inner rows of finer setae on the tuft very much reduced, while the outer row is of longer and heavier setae.

Phlebotomus vexillarius sp. nov.

Plate IV, figs. 31–41; plate VI, fig. 63; plate VII, fig. 73

Male.—Wing length 1.8 to 2.1 mm. A medium sized sandfly with mesonotum, head, abdominal tergites, pleura and coxae quite markedly infuscated. Abdominal setae apparently semi-erect. Post-spiracular setae present, 10 to 19 in number and 3 to 4 lower mesan-episternal setae. Proboscis a little less than head height. Palpi with segment V long, about equalling three preceding segments. Third antennal segment long, when in place on the head reaching to about the end of the third palpal segment. Ascoids short, hardly one-third the length of their respective segments, simple, paired on all but the last two segments. Newstead's scales few and slender, in a loose patch on distal third of third palpal segment. Wing venation as figured, veins clothed with setae except at extreme base where these are intermixed with ligulate striate scales. Cibarium with strong chitinous arch and narrow pigment patch but only faint vestiges of teeth. Pharynx posteriorly with numerous fine ridges.

Genitalia as figured, the specimen shown having lost one of the fan-like modified setae at the base of the coxite. Aedeagus stout and heavily sclerotized, the apex slender and turned downwards. Genital pump large, the filaments slender, a little more than twice as long as pump, their apices simple.

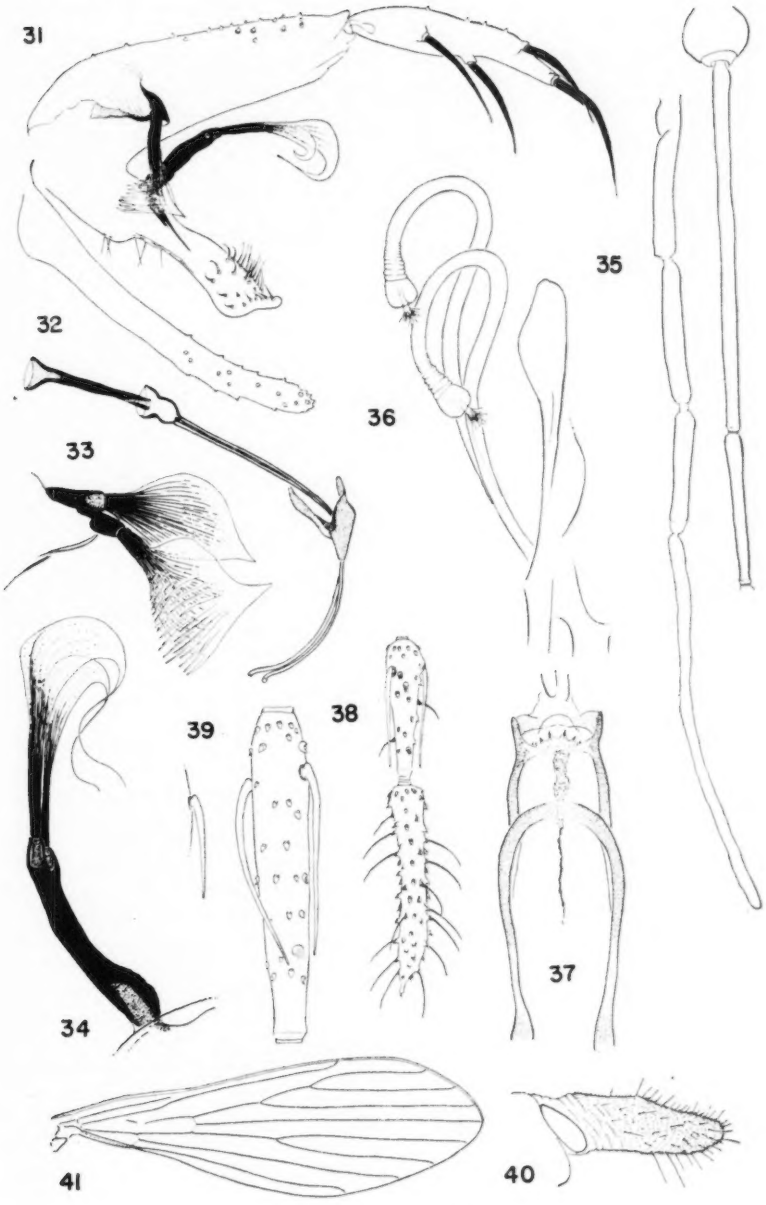
Female.—Wing length, 1.9 to 2.3 mm. Similar to male in color and vestiture. Proboscis a little longer than head height to base of clypeus. Third antennal segment reaching only to middle of third palpal segment and fifth palpal segment somewhat shorter than in male. Ascoids simple, much longer than in male, nearly reaching ends of their respective segments, present on all but the last segment, which is thickly beset with stout erect setae and is longer than either of the two next preceding segments. Cibarium and spermathecae as figured. Pharynx slender, with numerous fine ridges at proximal end, giving almost the appearance of being beset with fine hairs at right angles to its long axis. No setae (large deciduous hairs) on sides of eighth tergite nor scales on ninth tergite. Cerci slender.

Holotype male, slide 2151, Serrania Maje, Cerro Chucanti, Panama Province, Panama, 5 March, 1950, taken in tree buttress, R. Hartmann coll. *Allotype* female, slide 2319, Cerro Campana, Panama Province,

---

EXPLANATION OF PLATE IV

Phlebotomus vexillarius n. sp. FIG. 31, male genitalia, paratype, × 135. FIG. 32, pump and genital filaments, × 135. FIG. 33, modified spines on base of coxite, × 270. FIG. 34, modified spines on paramere, × 270. FIG. 35, basal antennal segments and palpi of male, × 135. FIG. 36, spermathecae, drawn in phenol, × 270. FIG. 37, female cibarium, × 270. FIG. 38, terminal antennal segments of female, × 200. FIG. 39, antennal segment IV of female and at left, ascoid of male, × 270. FIG. 40, female cercus, × 135. FIG. 41, male wing, × 32.


31
32
33
34
35
36
37
38
39
40
41

Panama, 25 Aug., 1950, taken in Shannon trap at light, M. Hertig coll. *Paratypes*, 6 male and 8 female specimens mounted in balsam on slides from the following localities: 2 males, same data as holotype; 1 male and 3 females, same locality as allotype, the male at light in a Shannon trap on 25 Aug., 1950, the females biting or resting on man, 9, 16 Aug., 2 Sept., 1950; 1 male, Rio del Medio, nr. Rio Gatun, C. Z., 15 Oct., 1949, in tree buttress; 1 male, Almirante, Bocas del Toro Province, Panama, 29 June, 1951, in tree buttress; 1 female, Tucue, Cocle Province, Panama, 19 July, 1950, biting man in daytime at ground level in the forest; 1 female, Cacique, Colon Province, Panama, 17 Sept., 1949, in tree buttress; 2 females, La Victoria, Cerro Jefe, nr. Pacora, Panama Province, Panama, 29 Dec., 1948, and 4 June, 1951, in light traps.

The name is from Latin *vexillum*, a flag or pennant, in reference to the structure of the modified setae on the coxite. We associate the sexes largely on the basis of structure of pharynx and cibarium and similarity of wing and palpal measurements. The appearance of the second sternite is also similar in the sexes. The species appears to be rare though widely distributed in heavily forested areas, and aside from the fact that it will bite man, we know nothing of its habits.

The bizarre development of the setae on the coxite and paramere are unique among American *Phlebotomus*, though approached by such species as *P. cruzi* Mang. and *P. edwardsi* Mang. The structure of cibarium, pharynx, spermathecae and style are not remarkable, and would place the species among a large group with four-toothed cibaria, unarmed pharynges, annulate spermathecae and a four-spined style, were it not for the unusual parameres. Armed parameres are uncommon in American *Phlebotomus*, and except for such aberrant groups as *Dampfomyia*, *Psychodopygus* and *Viannamyia*, occur only in the following species: *castroi* B. and C., *costalimai* Mang., *tupynambai* Mang., *williamsi* D., C. and A., *deanei* D. and A., *edwardsi* Mang., *longipalpis* L. & N., *cruzi* Mang. and *battistinii* Hertig. The first five of these have the paramere with only a single or double simple seta near the base, while the coxite bears a tuft of few to many simple setae. *P. edwardsi* bears four highly specialized setae on the paramere, but only simple setae on the coxite. *P. longipalpis* and *cruzi* are closely related species with two heavy setae on the parameres and more or less modified setae on the coxite. All the foregoing have four spines and an accessory seta on the style. The females of only *longipalpis* and *edwardsi* have been described. Both have annulate spermathecae, although those of *edwardsi* have only the terminal annulus retained. *P. longipalpis* has 10 teeth in an arched row in the cibarium, while *edwardsi* has 4 arranged much as in our species. *P. battistinii* has five heavy setae on the paramere and a group of variously modified spines on the coxite as well as five spines on the style. Its female has a four-toothed cibarium, and the spermatheca, from specimens in our possession, are annulate and somewhat like those of the present species.

On the whole, *vexillarius* appears to be a somewhat specialized and isolated form with no very close relatives, though probably derived from the same basic stock as the other species discussed above.

Phlebotomus triramulus sp. nov.

Plate V, figs. 42–51; plate VII, fig. 74

Male.—Wing length 1.74 to 2.16 mm. A large rather pale sandfly with the mesonotum but slightly infuscated. Post-spiracular setae 14 to 18, lower mesanepisternal setae 2 to 4, the latter narrowly ligulate. Abdominal setae erect, not scale-like. Proboscis a little less than head height. Basal antennal segments and palpi as figured. Newstead's scales rather long, in a loose patch on the middle third of the third palpal segment. Ascoids stout and long, equalling or exceeding their respective segments, without proximal prolongations, paired on all segments save the last two. Terminal segments not abruptly shortened. Wing as figured. Cibarium with a strong chitinous arch, incomplete in the middle, and with apparently four short rudimentary teeth. Pharynx as in female, with weakly denticulate ridges at posterior end. Genitalia as figured, the dorsal aspect of coxite thickly beset with deciduous ligulate scales, the external ventral aspect with semi-deciduous, rather stout and very long setae. Genital filaments somewhat more than three times as long as pump, their tips slightly expanded. Cerci as in female, though more slender.

Female.—Wing length 1.80 to 2.17 mm., as in male, though somewhat broader. Similar in color and setal arrangement to male, though there appear to be a few more post-spiracular setae. Setae on sides of eighth tergite usually absent, but rarely up to three may be present. Proboscis a little less than head height. Basal antennal segments and palpi as figured. Ascoids as in male, paired on all flagellar segments but the last. Newstead's scales as in male. Cibarium, spermathecae and cerci as figured, the abruptly digitate structure of the latter being unique so far as we know. Wing veins clothed with fine setae except at extreme base, where these are to a large extent replaced by ligulate square-ended scales.

Holotype male, slide 1754, Rio del Medio, near Rio Gatun, Colon Prov., Panama, 14 Oct., 1949, in tree buttress. R. Hartmann coll. *Allotype* female, slide 2376, La Victoria, Cerro Jefe, Panama Prov., R. P., 29 Aug., 1950, Yellow Fever Sta. C. at light in Shannon trap. Hertig and Galindo coll. *Paratypes*, 24 males, 36 females, mounted on slides from the following localities: Camp Chorrera, between Chorrera, Panama Prov., and the port, 18 March, 7 April and 9 July, 1944, in animal burrows; Barro Colorado Island, C. Z., 25 July, 1944, in animal burrow, O Mangabeira coll.; Cerro Campana, Panama Prov., 2000 ft. elev., 18 Jan., 1947, 4 July, 1948, in animal burrow, and 10 July, 1949, 2 Oct., 1949, in buttresses; La Victoria, Cerro Jefe, nr. Pacora, Panama Prov., 23 Jan., 1947, in animal burrow, 29 Aug. and 2 Sept., 1950, in Shannon trap at light, 5 Aug., 1951, in buttress, and 4 June, 1951, in mosquito light trap; Cerro Sta. Rita, Colon Prov., 6 May, 1948, in animal burrow; Cacique, Colon Prov., 17 Sept., 1949, in buttress; Palenque, Colon Prov., 14 Sept., 1949, in buttress and hollow tree; Rio del Medio, Rio Gatun, Colon Prov., 14 Oct., 1949, in buttress. In addition we have examined and identified, but not mounted, 545 males and 397 females from the above and the following additional locality: Mojinga swamp, nr. Gatun, C. Z., 15, 28 August,

4, 5, September, 4 October, 15, 26 November and 4 December, 1951, in mosquito light trap, F. S. Blanton coll.

The great bulk of this material was taken in animal burrows, or at light in a Shannon trap or mosquito light trap. On one notable occasion 467 specimens were taken from a single large burrow containing a "conejo pintado" (*Cuniculus paca*); many more could have been taken. Both sexes occurred in approximately equal numbers, but it is noteworthy that none of the females had fed. Only eight specimens were taken in buttresses and three in a hollow tree. Specimens have been taken in every month of the year save February, but most of the material was taken in the rainy season, from July to January. With the exception of Chorrera, all the localities from which this species has been collected were either on the Atlantic slope of the continental divide or at elevations of over 1500 ft. on the Pacific slope. The Chorrera locality was in a patch of scrubby woods near the edge of open grassy llanos; all the other localities are in heavy forest. The species has not been taken biting man or domestic animals and probably feeds on armadillos or some other burrowing mammal.

This species seems most closely related to *P. longispinus* Mang., *trichopygus* Floch and Abonnenc, *dasipodogeton* Castro, and *wagleyi* Causey and Damasceno. From all of these it differs in having the parameres three-branched, though the two distal branches are quite similar in shape to the corresponding structures in *longispinus* and *wagleyi*. In *trichopygus* and *dasipodogeton* it appears as though the two branches present on the parameres are homologous with the dorsal and ventral branches in the present species, the median clubbed branch being absent.

The females of *trichopygus* F. & A., *longispinus* Mang. and our species are quite similar, all having spermathecae with relatively short ducts, finely annulate or wrinkled globular or pear-shaped heads, and moderately protuberant terminal knobs. All have unarmed pharynges. *P. longispinus* and our species have four-toothed cibaria with patches of minute spines at the sides, while *trichopygus* has six well developed teeth.

Phlebotomus ylephiletor sp. nov.

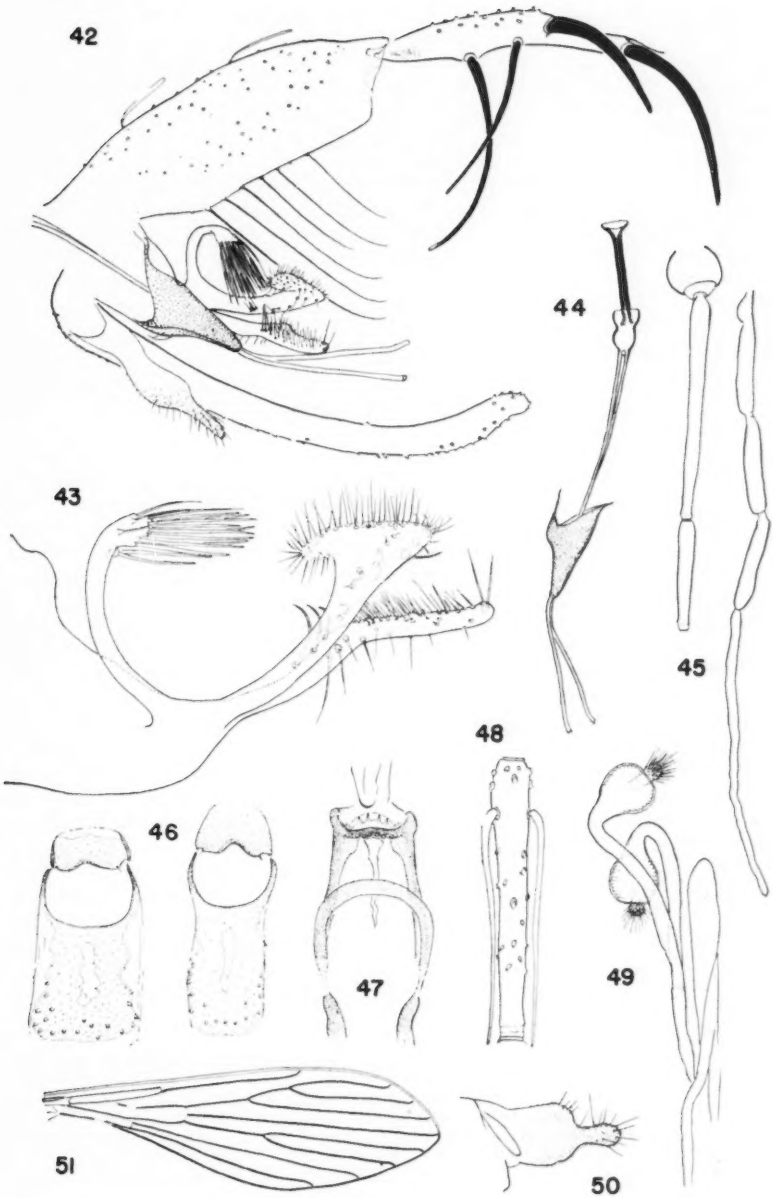
Plate VI, figs. 52–60

Male.—Wing length 1.65 to 1.80 mm. A rather small sandfly with the mesonotum and head quite strongly infuscated. Abdominal setae semi-erect, hair-like. Post spiracular setae present, 6 to 10 in number and 3 to 4 small lower mesanepisternal setae. Proboscis

---

EXPLANATION OF PLATE V

Phlebotomus triramulus n. sp. FIG. 42, male genitalia, holotype, × 167. FIG. 43, apex of paramere, drawn in phenol, × 270. FIG. 44, genital pump and filaments, × 135. FIG. 45, basal antennal segments and palpi of male, × 135. FIG. 46, first and second sternites, female left, male right, × 135. FIG. 47, female cibarium, × 270. FIG. 48, male antennal segment IV, × 270. FIG. 49, spermathecae, drawn in water after KOH treatment, × 270. FIG. 50, female cercus, × 135. FIG. 51, male wing, × 32.


42
44
43
45
48
46
47
49
51
50

about equalling head height. Palpi with segment V about as long as I+II, longer than III, IV very short, about twice as long as wide, as figured. Third antennal segment as figured, reaching to about the middle of palpal segment III. Newstead's scales scattered over the middle third of palpal segment III. Ascoids very slender and thin-walled, difficult to see, not reaching the ends of their respective segments, paired on all but the terminal three segments. Terminal three segments of antennae rather abruptly shorter than preceding segments, the last segment with unusually long tapering tip. Wing with venation as figured, clothed with seta except at base, where these are intermixed with ligulate, square-ended scales. Cibarium with strong chitinous arch and rounded pigment patch, without horizontal teeth, but with vestiges of vertical teeth. Pharynx rather broad and well sclerotized, but more slender than female, unarmed, but with digitate ridges.

Genitalia as figured, the genital pump rather heavy and the filaments stout, the latter about twice as long as the pump. Cerci short and unmodified.

Female.—Wing length 1.91 to 2.16 mm. Larger and more heavily pigmented than male, the fifth palpal segment shorter than segments I+II, and the third antennal segment reaching only to middle of segment II. Antennae and ascoids as in the male, the latter a little longer, absent on the shortened three terminal segments. Wing venation as in the male, the wing somewhat broader, but with similar ligulate striate scales at base.

Cibarium as figured, quite heavily sclerotized, the vertical teeth heavy and numerous, obscured by the round dark pigment patch. Pharynx quite broad, heavily sclerotized and pigmented, its apex unarmed, but with weakly denticulate ridges and obscure digitate processes. Proboscis greatly exceeding head height. Spermathecae as figured, the terminal knob very large, the annuli semi-telescopic, varying in number from 6 to 9, depending on the degree of enlargement of the incipient annuli at the base. Ducts rather short, about as long as stem of genital fork, fusing just before the vagina. A tuft of about 12 setae on lateral aspects of eighth tergite. Vestiture of ninth tergite composed of long stout setae and slender striate scales intermixed.

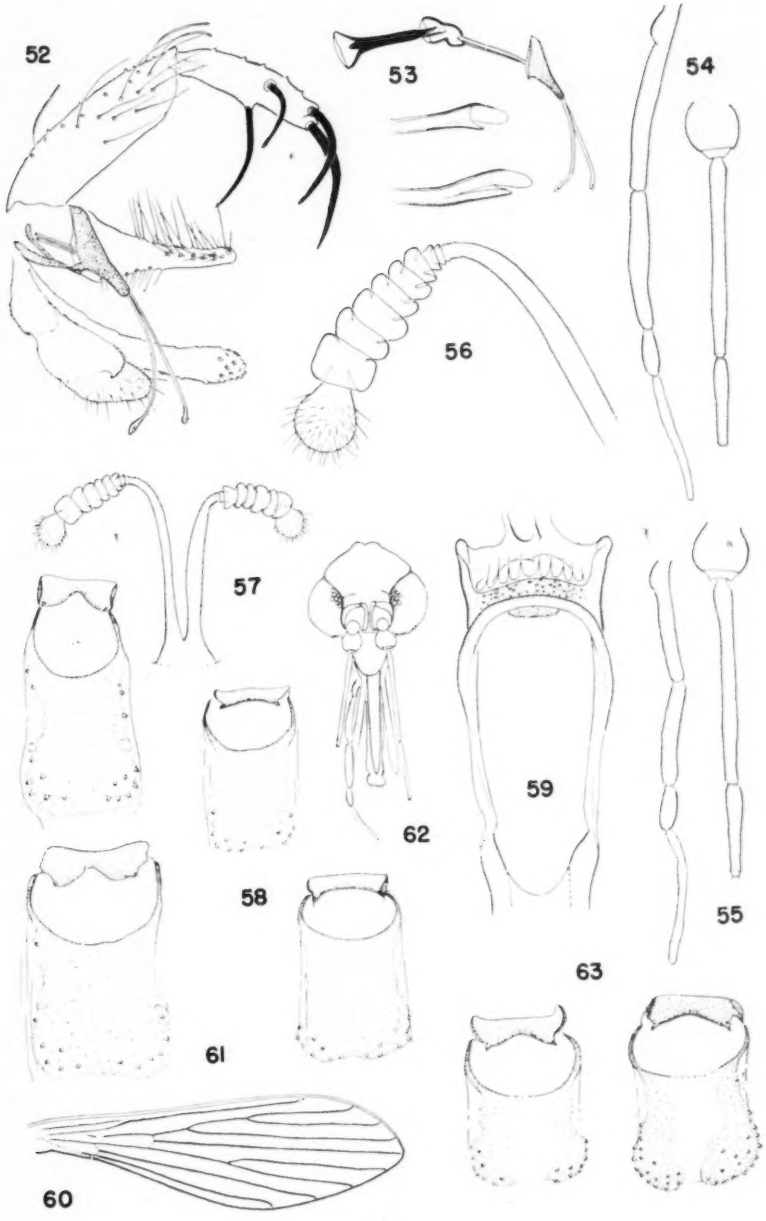
Holotype male, slide 2448, Finca Nievecita, Almirante, Bocas del Toro Province, Panama, 17 June, 1950, taken between buttressed roots of a forest tree, R. Hartmann coll. (The specimen has the left

EXPLANATION OF PLATE VI

Phlebotomus ylephiletor n. sp. FIG. 52, male genitalia, holotype, × 200. FIG. 53, genital pump and filaments, × 135, and tips of genital filaments, × 604.5. FIG. 54, basal antennal segments and palpi of female, × 135. FIG. 55, same of male, × 135. FIG. 56, spermatheca, head, × 604.5. FIG. 57, spermathecae, × 270. FIG. 58, first and second sternites, male above, female below, × 135. FIG. 59, female cibarium, × 270. FIG. 60, male wing, × 32.

Phlebotomus aclydiferus n. sp. FIG. 61, first and second sternites, male above, female below, × 135. FIG. 62, head, female, × 49.

Phlebotomus vexillarius n. sp. FIG. 63, first and second sternites, male left, female right, × 135.


52
53
54
56
57
62
59
55
58
63
61
60

antenna abnormal, the segments much shortened, but is selected as type because it is the specimen from which the figure of the genitalia was made.) *Allotype* female, slide 1690, Cacique, Colon Province, Panama, 17 Sept., 1949, in buttresses of large Ficus tree in forest, R. Hartmann coll. *Paratypes*, 96 males and 68 females mounted in copal-balsam on slides from the following localities: Juan Mina, Chagres river above Gamboa, Canal Zone, 1940, in mosquito light trap, D. M. Jobbins coll. (1 ♂); same locality, 3 Feb., 1947, in hollow tree with bats (1 ♂); same locality, 31 Jan., 1950, in mosquito light trap, Trapido coll. (1 ♂); Rio del Medio, Rio Gatun, Canal Zone, 14–15 Oct., 1949, in buttresses in forest, R. Hartmann coll. (17 ♂, 6 ♀); Gatun, Canal Zone, 29 Aug., 1951, in mosquito light trap, F. Blanton leg. (2 ♂, 4 ♀); Chilibrillo bat caves, near Chilibre, Panama Province, Panama, 28 Nov., 1946, in rock crevices near cave entrance, M. Hertig coll. (1 ♂); La Victoria, Cerro Jefe, near Tocumen, Panama Province, 29 Aug.-2 Sept., 1950, taken in a Shannon trap at light, M. Hertig and P. Galindo colls. (3 ♂, 2 ♀); Cerro Campana, Panama Province, 7 Jan., 1947, in buttresses in forest, 2500 ft. elev., M. Hertig and G. Fairchild colls. (2 ♂, 2 ♀); same locality, 2 Oct., 1949, Yellow Fever Station no. 2, in buttresses and hollow tree, Hertig & Trapido colls. (2 ♂, 1 ♀); El Valle de Anton, Cocle Province, 5 Nov. and 7 Dec., 1948, in buttresses, P Galindo colls. (2 ♂, 5 ♀); same locality, 21 and 31 March, 1945, biting man in the forest at night, Trapido, Michener and Middlekauff colls. (13 ♀); same locality, 16 May, 1948, in hollow tree, Fairchild coll. (1 ♀); Sta. Fe, Veraguas Province, Panama, 2 March, 1947, in buttresses in forest at about 2500 ft. elev., P. Galindo coll. (24♂, 21♀, two slides with 4 and one with 6 specimens); Cacique, Colon Province, Panama, 17 Sept., 1949, in buttresses in forest, R. Hartmann coll. (7 ♂, 2 ♀); Robalo, Bocas del Toro Province, Panama, 30 Jan., 1947, in buttresses, P. Galindo coll. (1 ♂); Finca Nievecita, Almirante, Bocas del Toro Province, 17–22 June, 1950, in buttresses, Hartmann coll. (12 ♂, 7 ♀); Finca dos Caños, Almirante, Bocas del Toro province, 18 June, 1950, in buttresses, Hartmann coll. (3 ♂, 2 ♀); Almirante, Bocas del Toro Province, 29 June, 1951, buttresses (2♂, 2 ♀); 26 July, 1951, Shannon trap at light (1 ♂) and 11 Sept., 1951, buttresses, all Quiñones coll.; Concepcion, Chiriqui Province, Panama, 10 Nov., 1949, buttresses in bamboo grove at 1600 ft. elev., Trapido coll. (2 ♂, 1 ♀); Rio Corotu, Puerto Armuelles, Chiriqui Province, 20 April, 1950, in buttresses, R. Hartmann coll. (4 ♂, 1 ♀); Puerto Armuelles, Chiriqui Province, 9 June, 1951, in Shannon trap at light, M. Hertig coll. (1 ♂, 1 ♀); Palo Santo, Chiriqui Province, 2 March, 1951, in buttresses, R. Hartmann coll. (2 ♂); La Tula, near El Naranjo, Chiriqui Province, 20 May, 1950, biting man in the forest, 10:45 A. M., 4800 ft. elev., R. Hartmann coll. (1 ♀); Esquinas, Puntarenas Province, Costa Rica, 28 Nov., 1949, in buttresses, Trapido coll. (1 ♂, 2 ♀); Palmar Puntarenas Province, Costa Rica, 27 Nov., 1948, under tree roots near pigpen, Trapido coll. (1 ♀); Palenque, Chiapas, Mexico, 30 March, to 1 April, 1951, in tunnel in ruins and in buttresses in vicinity of ruins, Fairchild & Hartmann colls. (4 ♂, 3 ♀).

In addition to the above slide mounts, we have examined and identified 3538 additional specimens of this species from the following

localities. Most of this material has been cleared in KOH and stored in alcohol. Almirante, Bocas del Toro Province, July, 1951, to February, 1952, in buttresses, at light, or biting at ground level at night (2874 specimens); Mojinga swamp, near Ft. Sherman, Canal Zone, Sept., Nov. and Dec., 1951, in mosquito light trap, F. Blanton leg., (12); Cerro Campana, Panama Province, July, Aug. and Feb., biting man in the forest, at light and in rock crevices (50); Sta. Fe, Veraguas Province, Panama, June, 1949, biting man at ground level in the forest (8 ♀); Madden Dam, Canal Zone, 21 Sept., 1951, in mosquito light trap, F. Blanton leg. (1 ♀); Palo Santo, Chiriqui Province, 20 Feb. to 2 March, 1951, biting man, mostly out doors at night, but once in a house and once in daytime, in buttresses, rock crevices and at light in a Shannon trap (50); Costa Rica, various localities in the general area of Turrialba, Pacuare, Suerre and S. Juan Miramar, Valle del General, mostly taken in buttresses in Jan. and July, 1951, and Jan. and Feb., 1952, by Rosabal and Hertig (91); Palenque, Chiapas, Mexico, 28 March to 2 April, 1951, in buttresses and temple ruins, Fairchild and Hartmann colls. (18 ♂, 1 ♀); Ocosocautla, Chiapas, Mexico, 8 April, 1951, in shallow buttresses and holes in oak trees, Fairchild & Hartmann colls. (9 ♂).

This species belongs to a group of very similar appearing species, including *P. intermedius* L. & N., *whitmani* Antunes & Coutinho, *sylvicolus* F. & A., *anduzei* Rozeb., *trapidoi* n. sp. and a number of others with four spines on the style, simple parameres, rather short fifth palpal segment and with delta of the wing venation long, usually at least half as long as alpha.

From *intermedius* it can be separated in the male by the shorter lateral lobes, but little longer than the parameres and hardly twice as long as the cerci, the less modified tips of genital filaments, the more nearly paired terminal spines of the style, and by lighter pigmentation of thorax and head. In the female the spermathecae of *ylephiletor* have a relatively much larger terminal knob, the terminal annulus is enlarged, and the remaining annuli are fewer in number, 6 or 7, and decrease in size from apex to junction with the duct. The annuli are also semi-telescopic and there are several small incipient annuli at the base. In *intermedius* the annuli are of rather uniform size throughout, 10 to 12 in number and are not reduced much in size towards the base. The cibaria of both species are very similar and not certainly distinctive.

From *anduzei*, based on the description of Floch and Abonnenc (1944), *ylephiletor* differs very little. The terminal spines of the style are closer together in the latter species, the parameres relatively longer and the aedeagus more slender, not abruptly truncated. The genital filaments are also slightly longer, about twice as long as the pump. In the female, the spermathecae of *ylephiletor* have many fewer annuli and smooth rather than wrinkled ducts. The cibaria of the two species seem very similar, not separable with certainty.

From *sylvicolus* F. & A., also based solely on the original description, the present species differs in a blunter aedeagus, shorter genital filaments relative to the pump, relatively longer parameres and a blunter and more cylindrical style. In *sylvicolus* the style is about half the

length of the coxite, while in the present species it is fully three-fourths as long. The differences are difficult to describe, yet the figures give a quite distinct impression, and we believe comparison of actual specimens would show other differences.

From *whitmani* our species can readily be distinguished in the male by its much shorter and stouter genital filaments and heavier genital pump, by the blunter tips to the aedeagus, acutely pointed in *whitmani*, by the stouter and shorter parameres, and by the more nearly paired terminal spines of the style. In the female, the spermathecae of *whitmani* have many more and smaller annuli, a smaller terminal knob, and longer ducts. The cibaria of both are of the same type, not distinguishable with certainty, and both have dark heads and mesonota.

From *trapidoi* both sexes can be separated by the color of head and mesonotum, *trapidoi* being nearly without pigmentation. *P. trapidoi* has relatively longer coxites, style and lateral lobes, more slender parameres, the terminal spines on the style well separated and slightly shorter genital filaments with their tips merely slightly dilated. In the female the spermathecae of *trapidoi* have fewer and more uniform annuli, five to six, and no incipient annuli at the junction of the duct. The terminal knob is also broader based, less pedunculate, than in *ylephiletor*. The cibaria are not distinguishable with certainty.

The two species *ylephiletor* and *trapidoi* were at first not recognized as separate by us. Study of the very extensive material now available has enabled us to separate them easily on color, *ylephiletor* having a strikingly dark head and mesonotum. Spermathecae and style also show constant differences. Though both species attack man readily and are, in general, found together, *trapidoi* is very abundant in the tree tops while *ylephiletor* is very rare there, though it may be abundant near the foot of the same tree. *P. ylephiletor* is the dominant species in a number of localities at higher elevations in Chiriqui Province where *trapidoi* seems not to occur.

Phlebotomus trapidoi sp. nov.

Plate VII, figs. 64–72

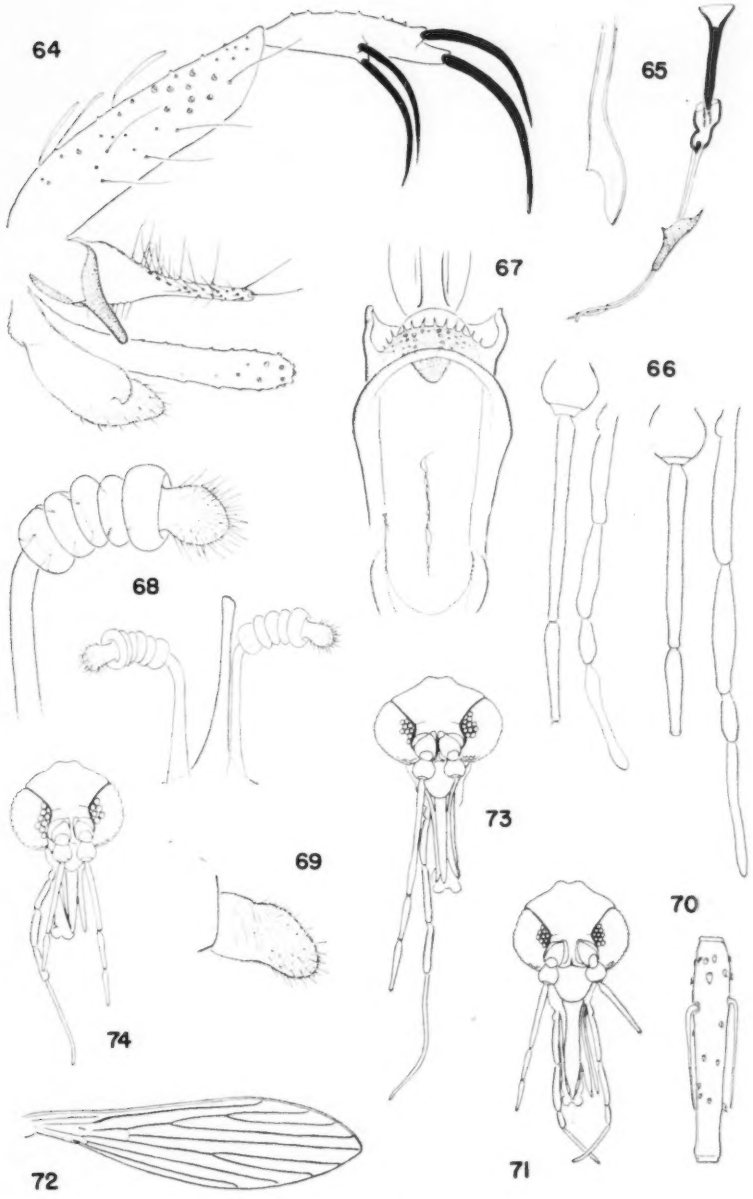
Male.—Wing length 1.49 to 1.74 mm. A small pale sandfly, the mesonotum and head not noticeably infuscated. Abdominal setae semi-erect. Post spiracular setae 4 to 6, lower mesanepisternal setae 3 to 5. Proboscis slightly less than head height. Fifth palpal segment longer than third, about equal to first and second together, as figured.

EXPLANATION OF PLATE VII

Phlebotomus trapidoi n. sp. FIG. 64, male genitalia, holotype, × 200. FIG. 65, pump and genital filaments, × 135, and tip of genital filament, × 604.5. FIG. 66, basal antennal segments and palpus of male, left and female, right, × 135. FIG. 67, female cibarium, × 270. FIG. 68, spermathecae, upper, × 604.5, lower × 270. FIG. 69, female cercus, × 135. FIG. 70, antennal segment IV of male, × 270. FIG. 71, female head, × 49. FIG. 72, male wing, × 32.

Phlebotomus vexillarius n. sp. FIG. 73, female head, × 49.

Phlebotomus triramulus n. sp. FIG. 74, female head, × 49.


64
65
67
66
68
73
69
70
74
72
71

Third antennal segment as figured, reaching beyond end of third palpal segment. Newstead's scales in a loose patch on middle third of third palpal segment. Ascoids simple, very thin-walled and difficult to see, not reaching ends of their respective segments and paired on all segments except the terminal three, which are abruptly shortened. Wing venation as figured, the veins clothed with hairs except of extreme base, where these are mixed with ligulate striate scales.

Cibarium with a strong chitinous arch, numerous minute erect teeth but no horizontal teeth, and a narrow triangular pigment patch. Pharynx slender, poorly sclerotized, unarmed but with fairly strong ridges or wrinkles at its posterior end. Genitalia as figured, the coxites clothed dorsally with rather numerous ligulate striate scales and with several irregular rows of fairly strong long setae on the lateral lower aspect, not shown in the figure. Genital pump fairly heavy, the filaments moderately stout, the latter about 1.5 times as long as the pump. Cerci of normal shape.

Female.—Wing length 1.89 to 2.01 mm. Similar to the male in external characters and color, though the mesonotum somewhat darker. Fifth palpal segment about equal to third, shorter than first and second together. Third antennal segment not reaching end of second palpal segment. Newstead's scales as in male. Ascoids and terminal antennal segments as in male, though the former somewhat longer. Wings as in male though relatively broader.

Cibarium as figured, often only 10 or 11 horizontal teeth visible. Pharynx rather broad, not strongly pigmented, unarmed except for weak digitate processes and transverse ridges. Spermathecae as figured, usually with five annuli, rarely with six, the annuli of the same diameter and no incipient annuli at the junction of the duct with the spermathecal body. Ducts opening separately into the vagina. Eighth tergite with a patch of setae laterally. Ninth tergite with numerous lorate or ligulate striate scales dorsally. Cerci short, of normal shape.

Holotype male, slide 3291, Almirante, Bocas del Toro Province, Panama, 19 June, 1951; taken between buttressed roots of large tree at Yellow Fever Station D; Quiñones coll. *Allotype* female, slide 2474, Finca Nievecita, Almirante, Bocas del Toro Province, Panama, 21 June, 1950; taken between buttressed roots of large tree, R. Hartmann coll. *Paratypes*, 21 males and 22 females mounted in copal-balsam from the following localities: El Valle, Cocle Province, Panama, 31 March, 1945, biting or resting on man in the forest, 9 P. M., H. Trapido and C. D. Michener colls. (1 ♂, 3 ♀); Madden Field, near Calzada Larga, Panama Province, Panama, 30 Oct. to 5 Nov., 1945, biting man, Marucci and Wood colls. (4 ♀); Cerro Campana, Panama Province, Panama. 17 Jan., 1947, in buttress in forest at 2500 ft. elev., Hertig & Fairchild colls. (1 ♂); Robalo, Bocas del Toro Province, Panama, 30 Jan., 1947, in buttress in forest, P. Galindo coll. (1 ♂); Sta. Fe, Veraguas Province, Panama, 20 March, 1947, in buttresses in forest at 2500 ft. elev., P. Galindo coll. (2 ♂); Upper Rio Las Cascadas, nr. La Victoria, Cerro Jefe, Panama Province, Panama, 26 Feb., 1948, at light, P Galindo coll. (2 ♀); La Victoria, Cerro Jefe, nr. Tocumen, Panama Province, Panama, 29 Dec., 1948, in an automatic mosquito light trap in forest at 2300 ft. elev. (1 ♂); Quebrada Escondida, upper

Rio Pequeni, Panama Province, Panama, 26 March, 1949, Galindo & Trapido colls. (1 ♀); Palenque, Colon Province, Panama, 14–15 Sept., 1949, in buttresses and large hollow tree in forest, R. Hartmann coll. (7♂, 4♀); Cacique, Colon Province, Panama, 17 Sept., 1949, in buttresses in forest, R. Hartmann coll. (2 ♂); Rio del Medio, Rio Gatun, Canal Zone, 15 Oct., 1949, in buttress in forest, R. Hartmann coll. (1 ♂); Finca Nievecita, Almirante, Bocas del Toro Province, Panama, 15–22 June, 1950, in buttresses in forest, R. Hartmann coll. (5 ♂, 3 ♀); Finca dos Caños, Almirante, Bocas del Toro Province, 18 June, 1950, in buttresses, R. Hartmann coll. (2 ♀); Almirante, Bocas del Toro Province, 29 June, 1951, in buttresses near Yellow Fever Stations, Quiñones coll. (3 ♀).

In addition to the mounted material listed above, we have examined 3065 specimens, about equally divided as to sex, which have been cleared in KOH and stored in alcohol. The bulk of this material (2495 specimens) is from Almirante, mostly taken biting man at night or resting on tree trunks at platforms built in the tree tops (1949 specimens); 412 specimens were from mosquito light traps run in Mojinga swamp, near Ft. Sherman, C. Z., while the remainder represent scattered small lots from Gatun, Madden Dam, Loma Borracha and Mindi dairy in the Canal Zone, La Victoria and the Pacora area east of Panama city, mostly taken in light traps, and two small lots from Cacique, Colon Prov., October, taken biting in the forest by day and El Real, Darien, taken biting in the tree tops in July. There are also 29 specimens from various localities in the neighborhood of Turrialba, Costa Rica, mostly from buttresses. Finally, through the kindness Dr. Luis A. Leon, of Quito, Ecuador, we have received a small lot of females of this species from Quevedos, Ecuador. These were taken biting man with *P. gomezi*, but whether in houses or outdoors is not known. This represents the first record, to our knowledge, of *Phlebotomus* from Ecuador.

Our records show that the species has been taken in every month of the year, though more abundantly from August to January. The bulk of the material was collected biting man at night in the tree tops or resting on the tree trunks nearby. It has also been taken biting man at ground level in the forest, both day and night, though in far less numbers. Mosquito light traps and Shannon traps with gasoline lantern have taken over 800 specimens. It is occasionally fairly common in buttresses, over 200 specimens, and has been secured once from an animal burrow and once, 21 specimens, from a hollow tree. Although other species are taken in the tree top catches, *trapidoi* is overwhelmingly the dominant species and is relatively scarce elsewhere, if collections at light are excluded. It appears to be as definitely arboreal as are such mosquitoes as *Haemagogus spegazzinii* and *Sabethes chloropterus*, at least in the adult stage.

The distribution in Panama is probably wider than our records indicate, as its tree-top habitat has been explored in only a few localities. As would be expected, most of the localities are in areas of heavy forest and abundant rainfall. It has been taken at seven places in the Canal Zone, all on the Atlantic side of the continental divide, three localities in Colon Province and four in Bocas del Toro Province, all

on the Atlantic side. Of the three localities in Panama Province, two are at elevations of over 1000 ft. in wet mountain forest, the third in heavy lowland forest near the coast. The single collection from Veraguas Province was also in wet mountain forest, while the singel collection from Darien Province was at a tree-top station in high virgin forest. The Costa Rican material was all from wet forest on the Atlantic slope. Rather extensive collections from Chriqui Province, and the Pacific slope of adjoining Costa Rica have not yielded this species, though both light trap and some night collecting in tree tops has been done.

We take great pleasure in dedicating this species to our colleague, Dr. Harold Trapido, who has been an indefatigable collector of *Phlebotomus* and whose studies of forest canopy mosquitoes led to the discovery of the arboreal habitat of this interesting species.

The close relationship of the two preceding species, *ylephiletor* and *trapidoi*, to *whitmani* of Brasil and Paraguay, which is stated by Barretto (1943) to be the commonest species biting man in zones of high leishmaniasis endemicity in Sao Paulo and which was found by Hertig in a recent survey to be the commonest species in the endemic zones of Paraguay, suggests that they may be of importance in the transmission of that disease in Panama. Although hardly conclusive, it is of interest to note that the collector who for nearly a year made the weekly tree-top catches at our Almirante station contracted cutaneous leishmaniasis. In French Guiana, Floch and Abonnenc state (1946) that *anduzei*, another closely related species, is the commonest species in the Colony and bites man readily.

REFERENCES

Barretto, M. P. 1943. Observacoes sobre a biologia, em condicoes naturais, dos Flebotomos do Estato de Sao Paulo. Tese da Faculdade de Medicina da Univ. S. Paulo, Sao Paulo, 1943.

Floch, H., and **Abonnenc, E.** 1941. Phlebotomes de la Guyane Francaise. Inst. Pasteur de la Guyane, Pub. no. 15, pp. 7–13, figs. 3–4.

Floch, H., and **Abonnenc, E.** 1944. Phlebotomes de la Guyane Francaise. X. Sur les femelles a 5e segment des palpes court. Description du male de *P. anduzei*. Inst. Past. de la Guyane, Pub. No. 88, pp. 13–15, figs. 12–13.

Floch, H., and **Abonnenc, E.** 1946. Distribution des Phlebotomes en Guyane Francaise. Inst. Past. Guyane, Pub. 142.

Mangabeira, O. 1942. 7ª contribuicao ao estudo dos Flebotomus. Descricao dos machos de 24 novas especies. Mem. Inst. Osw. Cruz, 37 (2): 119–132.

Mangabeira, O. 1942a. 9ª contribuicao ao estudo dos Flebotomus, *Flebotomus* (*Pressatia*) *triacanthus* Mang. Mem. Inst. Osw. Cruz, 37 (3): 241–250, 12 figs.

A NEW NAME FOR THE BEE GENUS RUIZIELLA

Recently the undersigned erected a new genus of Panurgine bees, *Ruiziella*, with *Camptopoeum ochraceum* Friese as the type. This was published in the March number of the Annals (p. 105) which appeared early in April, 1952. Dr. Raúl Cortés also has published a genus of Tachinidae of the same name in the new journal "Revista Chilena de Entomologia," Volume 1, p. 251 and 254. This issue is dated "1951," but Dr. Cortés has informed me that it was published about the first of March, 1952. For the bee genus the new name *Ruziapis* is hereby proposed.—P. H. Timberlake.

THE TAXONOMIC STATUS OF THE AEDES LEUCOCELAENUS COMPLEX WITH DESCRIPTIONS OF TWO NEW FORMS

(Diptera, Culicidae)[1, 2]

PEDRO GALINDO,[3] STANLEY J. CARPENTER,[4] AND HAROLD TRAPIDO[3]

The incrimination of *Aedes leucocelaenus* Dyar and Shannon as a vector of sylvan yellow fever in Brazil has stimulated interest in this mosquito, since according to Lane (1939) it has a very wide range in the American tropics, extending from Panama south to Argentina.

The species was described by Lutz (1904) from females taken in the states of Rio de Janeiro and Sao Paulo, Brazil, under the name *leucomelas*. Since this name was preoccupied by *leucomelas* Meigen, 1804, Dyar and Shannon (1924) proposed the name *leucocelaenus*.

Dyar (1928) described what he thought was the male of this species from a specimen taken in Panama, but Komp (1938) in restudying Dyar's specimens and fresh material collected by himself in Panama, came to the conclusion that the Panama form represented a distinct species, and described it under the name *leucotaeniatus*. In the same publication Komp described and figured what he considered the male of *leucocelaenus* from "three specimens, one from Brazil, one from Argentina and one from Colombia," and also gave a description of the larva from specimens obtained "at Restrepo, Colombia and at Mazaruni, British Guiana."

Later, in a personal communication to the senior author, Komp stated that he had found two forms to be present in Panama. The authors (Galindo, Trapido and Carpenter, 1950) confirmed Komp's findings and reported two species from Panama, one which was definitely established as *Aedes leucotaeniatus* Komp, and the other which was assumed to be *Aedes leucocelaenus* D. & Sh. During the dry season of 1950 we had the opportunity of mounting a large series of male terminalia, larval skins, and pupal cases of what was thought to be *A. leucocelaenus* collected by us in Panama, in the course of sylvan yellow fever investigations. In studying this material we became impressed with some wide differences which we found between the male terminalia and larval skins of our specimens, and the descriptions and figures given by Komp for his South American material. In order to determine with certainty the identity of our species, we wrote Dr. Henry Kumm requesting reared material from Brazil. Dr. Kumm was able to send

[1]Studies on The Forest Mosquitoes of Panama. VI.

[2]Publication costs paid by the Gorgas Memorial Institute.

[3]Gorgas Memorial Laboratory, Apartado 1252, Panama, R. de P.

[4]Colonel M.S.C., U. S. Army Caribbean, Fort Clayton, Canal Zone.

us, through the courtesy of Dr. Waldemar Antunes of the Yellow Fever Service of Brazil, a small series of males and females with corresponding larval and pupal skins taken at Tarauaca, Territorio do Acre, Brazil, on July 26th, 1949, at Feijo, Territorio do Acre, on September 4th, 1949, labeled "*Aedes* (*Finlaya*) *leucocelaenus* Dyar and Shannon." These specimens proved to be very different from the Panama form in characters of the male terminalia, larvae and pupae. The male terminalia also differed markedly from Komp's descriptions and figures.

At this time we also became impressed with the fact that the best characters to separate the species of this group are to be found in the pupa, particularly in the shape of the paddle, its terminal hair and hair 2 of segment I (terminology of Knight and Chamberlain, 1948).

Since Territorio do Acre is located more than a thousand miles from the type locality of *leucocelaenus*, we were then still uncertain as to the true identity of this species. We therefore wrote again to Dr. Kumm asking for reared material from the type locality of *leucocelaenus*. In the absence of Dr. Kumm, Dr. Ottis R. Causey shipped us a series of males and females from the States of Rio de Janeiro and Sao Paulo (type locality of the cotype series), but unfortunately he was unable to obtain pupal cases for us. The males from the type locality proved to have terminalia similar to the Panama males. At this time we also sent illustrations of the male terminalia, larvae, and pupae of the Panama and Territorio do Acre forms to Dr. John Lane of the University of Sao Paulo, asking him to compare them with topotypical material of *A. leucocelaenus* in his collection. This Dr. Lane kindly did. He has written to us (letter dated November 27th, 1950) as follows: "Our topotypical material of *Aedes leucocelaenus* is completely different from the species which you determined as such from material collected in Territorio do Acre, Brazil, as per exam of pupal pelts. It is near (but different) from your *Aedes* n. sp. collected in Panama and Costa Rica as per pupal pelts. The shape of the paddle (in *Aedes leucocelaenus* from Sao Paulo) is evenly ovoid and *does not* show the kink from which the apical hair inserts itself. The apical hair is, at most, half as long as the length of the paddle and not about one and a half times the length of the paddle as shown in your illustration. Based on pupal characters both your illustrations show other species which, to my way of thinking, are subspecies or, better still, new species."

Subsequently we obtained associated material from Sao Paulo, sent to us by Dr. Lane, and from Rio de Janeiro, through the courtesy of Dr. H. A. Penna of the Institute Oswaldo Cruz. A comparative study of this material with Panamanian and Costa Rican specimens reveals that the Sao Paulo and Central American forms are strikingly different, particularly in pupal characters, but that, although the greater bulk of the material from Rio de Janeiro appears exactly like the Sao Paulo form, some specimens from this locality show various degrees of intergradation. Dr. W. H. W. Komp (*in litt.*) informs us that *leucocelaenus* material studied by him from Trinidad and from Rio de Janeiro resembles closely the Central American form.

These facts lead us to believe that we are dealing with but a single species which extends from Costa Rica along the east coast of South America to Argentina and which breaks up into two subspecies at the

extreme ends of its geographical distribution, with intergrading forms occurring throughout the rest of its range.

The present status of the *leucocelaenus* group of species, in our opinion, is then as follows:

1. There is one species of the complex extending from Costa Rica, along the east coast of South America, to Argentina. This species breaks up into two subspecies at the extreme ends of its range, namely *Aedes leucocelaenus leucocelaenus* Dyar and Shannon occurring in southern Brazil and Argentina and *Aedes leucocelaenus clarki* n. ssp. which has been found in Panama and Costa Rica.

2. In Territorio do Acre, on the eastern slopes of the Andes, there is a distinct species which we are describing in this paper as *Aedes leucophoebus* n. sp., which may be separated from the true *leucocelaenus* on larval, pupal and male terminalia characters.

3. In Panama and Costa Rica, besides *Aedes leucocelaenus clarki* n. ssp. there also occurs another species, namely, *Aedes leucotaeniatus* Komp which may readily be separated from other species of the complex by larval, pupal, female and male terminalia characters.

4. The male illustrated by Komp (*loc. cit.*) without definite locality neither corresponds with the topotypical males of true *leucocelaenus* in our collection, nor with the two new forms described in this paper. Komp has informed us (in a letter to H. T. dated April 18th, 1951) that this illustration was drawn from a male taken at Restrepo, Colombia, and that a comparison of males, larvae and pupae from Restrepo, with material and figures of *Aedes leucocelaenus*, ss. pp. *Aedes leucotaeniatus*, and *Aedes leucophoebus* n. sp., reveals that the Colombian form is distinct, representing the fifth member of the complex. This new species will be described by Komp separately.

Aedes (Finlaya) leucocelaenus clarki new subspecies

Holotype Male.—Head: Proboscis long and slender, longer than fore femur, shining black. Palpi dark and long, about four-fifths the length of the proboscis. Antennae plumose, slightly more than half as long as the proboscis. Clypeus shining black. Occiput clothed with shining black ovoid scales and a few erect forked ones posteriorly, with a median stripe of silvery scales and a narrow line of snowy white scales bordering the eye and joining a broad silvery patch below.

Thorax (Plate I, fig. G): Anterior pronotal lobes with silvery scales on anterior half and shining black scales posteriorly. Mesonotum covered with metallic black scales except for a broad median stripe and four patches of snowy white scales, two small ones located just back of the anterior angles of the mesonotum and two large ones above and directly in front of the roots of the wings. Scutellum concolorous with mesonotum with some silvery scales medianly. Pleuron black except for the following patches of snowy white scales: a small spot on the propleuron, a patch on the posterior pronotum contiguous with the patch near the anterior angle of the mesonotum, a large patch cutting across the sternopleuron and joining the two patches mentioned above to form a long broad stripe. A quadrate patch on the upper sternopleuron joining through a small group of silvery scales on the para-

tergite with the large mesonotal patch above the roots of the wings, a long bar-shaped patch cutting diagonally across the mesepimeron. (In some paratype specimens there is a short spur pointing back towards the dorsoposterior angle of this sclerite.) This patch joins the patches on the upper sternopleuron, paratergite and mesonotum to form a second broad pleural stripe. Pleural chaetotaxy as follows: three posterior pronotals, no spiraculars, a single postspiracular, a single lower sternopleural, a patch of prealars and a single isolated seta located between the prealars and the lower sternopleural. Upper mesepimerals present. Coxae with a large patch of silvery scales on anterior half. Trochanters almost entirely clothed with silvery white scales. Femora, tibiae and tarsi irridescent black except for the following silvery white markings: fore femur with two short basal narrow lines of silvery scales on the anterodorsal and anteroventral surfaces. Mid-femur with a rounded snowy white spot on the outer third of the dorsal surface joining a narrow concolorous line on the anteroventral surface which runs from the spot back to the base of the femur. Tip of femur with a silvery white spot on the dorsal surface which almost rings the joint. Hind femur entirely silvery white scaled on the dorsal surface from base to outer third; tip broadly white. Postnotum covered with white pubescence. Wing scales elongate, dark.

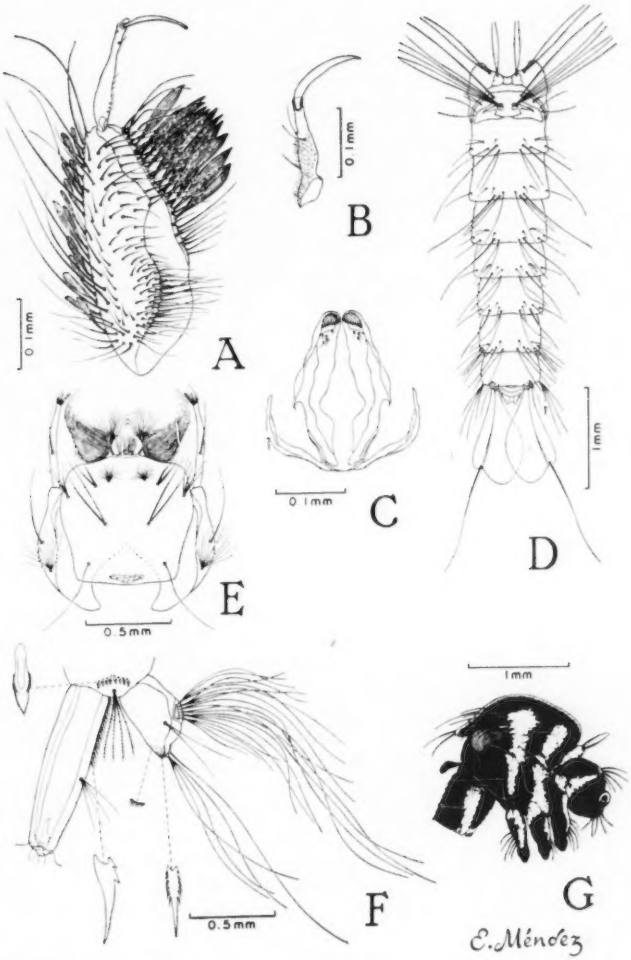
Abdomen: Tergites shining black with lateral basal white spots, those on first two segments confluent. Venter shining black with broad basal silvery white stripes, broad at the pleural line and narrowing medianly.

Male terminalia: Basistyle (Plate I, fig. A) about two and a half times longer than its greatest width. Dorsal surface with long stiff hairs and short, truncate ribbed scales. Ventral surface with abundant long petiolate ribbed pointed scales distally, and a row of long strong hairs which tend to form a patch basally. Dististyle between one-third and one-half the length of the basistyle, tapering from base to tip, with a row of fine pile on the basal ventral margin and two small setae just before the tip. Terminal spine very long more than half the length of the dististyle.

Claspette (Plate I, fig. B) short, stem curving sharply laterally before the middle so that in lateral view it appears to bulge at this point and then to taper to tip. Stem densely clothed with short hairs on basal two-thirds and with three modified setae from outstanding tubercles, (see taxonomic discussion), two from the dorsal surface, one near the base, one near the tip and a third on the ventral surface just basal to the apical dorsal seta. Filament sickle shaped, as long as the stem. Ninth tergite (Plate I, fig. C) formed by two lateral thin, broad plates united by a short thin membrane which tends to tear during dissection. Tenth sternites straight with hooded tips ending in a comb-like structure. Mesosome tubular with an excavation just before tip and two small chitinous bars on each side of it.

Female.—Coloration similar to male. Palpi short, antenae not plumose.

Larva (Plate I, fig. E).—Head globular, antennae small and glabrous, antennal hair single, inserted slightly basal of the middle of segment. Head hairs arranged as follows: "B" double, "C" single or double,



Aedes (*Finlaya*) *leucocelaenus clarki* n. sp. FIG. A. Style. FIG. B. Claspette. FIG. C. Ninth tergite and tenth sternites. FIG. D. Abdomen of pupa (dorsal view). FIG. E. Head of larva (dorsal view). FIG. F. Terminal segments of larva. FIG. G. Lateral view of adult.

"A" double or triple, "e" single and long, "f" short and multiple, "d" short and multiple (Hopkins, 1936, terminology). Body integument glabrous. Subdorsal abdominal hairs in very weak, short tufts. Lateral abdominal hairs double on segments I and II, single and long on segments III to VII. Lateral comb of eighth segment (Plate I, fig. F) of eight scales in a single row. Individual scales spine-like, weakly and evenly fringed. Air-tube long for the subgenus, nearly four times as long as its basal width, slightly tapering on outer half, with some 15 to 18 pecten teeth and a short three-haired (four-haired in some paratypes) ventral tuft located slightly beyond the middle. Anal segment longer than wide, anal saddle not ringing the segment, covered with spinules on dorsoposterior angle. Anal hair as follows: dorsal tuft consisting of two branches inserted on a chitinous plate, dorsal branch a four-haired tuft, (varying from four- to eight-haired in the paratype series) ventral branch single. Lateral hair double. Ventral brush inserted on a chitinous arch which is preceded by a small triangular sclerotized plate.

Pupa (Plate I, fig. D).—Trumpet long and tubular, about five times as long as its greatest width. Abdominal chaetotaxy as follows (Knight and Chamberlain, 1948, terminology): hair 2 on segment I a long tuft with five branches, longer than the sum of the lengths of segments II and III. Hair 5 single on segments II to VII, very long on segments II, III and IV, usually as long or longer than the sum of the lengths of the two segments posterior to the one on which it is inserted, shorter on segments V, VI and VII where it only exceeds the length of the segment immediately posterior to the one on which it is inserted. Hair 2 double on segments II to VII slightly less than half the size of hair 5 on segments II, III and IV and about equal in size to this hair on segments V, VI and VII. Hairs 7 and 8 double on segment VII. Hair 8 a four-haired tuft on segment VIII. Paddles long, longer than segments VII and VIII together and fan-shaped, with an indentation at the point where the apical hair is inserted. Midrib broadening from base to apex and dividing the paddle into a narrow outer portion and a broad and rounded inner part. Apical hair single and very long, being about one and one-half times the length of the paddle.

Type Material.—Holotype: Pinned male with terminalia, larval and pupal skins mounted on two slides, reared from eggs laid by a female taken biting man in the forest at Tucue, Province of Cocle, Republic of Panama, on September 5th, 1950. *Allotype:* Pinned female with larval and pupal skins mounted on a slide; same data as holotype. *Paratypes:* One whole pinned male with larval and pupal skins mounted on one slide; same data as holotype. Two whole pinned males, five pinned males with terminalia mounted on slides, and four pinned females, with corresponding larval and pupal skins mounted on slides taken at La Victoria, (altitude 400 feet), Province of Panama, Republic of Panama, on June 14th, 1949; August 23rd, 1949; November 8th, 1949, January 31st 1950. One pinned male and one pinned female with male terminalia, larval and pupal skins mounted on slides taken at La Victoria, (altitude 1000 feet) on August 3rd, 1949. The types are to be deposited at U. S. National Museum, Washington, D. C.

We take pleasure in naming this subspecies for Dr. Herbert C. Clark, Director of the Gorgas Memorial Laboratory.

Aedes (Finlaya) leucophoebus n. sp.

Holotype Male.—Coloration and morphology as described for *A. leucocelaenus clarki* except for the silvery patch on mesepimeron which in the holotype and one paratype male shows a more pronounced spur pointing back toward the dorsoposterior angle of the sclerite, being thus intermediate between *A. leucocelaenus clarki* and *A. leucotaeniatus* (Plate II, fig. G).

Male terminalia (Plate II, fig. A): Basistyle short, sharply tapering toward tip. Ventral distal margin with abundant long, petiolate ribbed scales and a row of long, strong, evenly distributed hairs. A patch of long, very strong hairs near the base. Dorsal surface with scattered long setae (no scales were noted in this area in the two preparations examined). Dististyle between one-third and one-half the length of the basistyle, sinuate and narrow with a row of fine pile on the inner margin extending for two-thirds of its length, and a stronger seta on the lateral inner aspect just before the tip. Terminal spine very long about one half the length of the clasper. Claspette (Plate II, fig. B) slender, stem curving laterally before the middle and then bending ventrally just before apex, densely clothed on basal two-thirds with fine setae and bearing two stronger differentiated hairs on the dorsal margin, one rather long arising near the base of the stem, and the second one weaker and shorter arising just before the ventral curvature of the stem on the outer third. Filament sickle-shaped tapering abruptly from base to tip, about two-thirds the length of the stem. Ninth tergite (Plate II, fig. C) with two thin, broad lateral plates joined in the center by a long sclerotized bar. Tenth sternites and mesosome as in *A. leucocelaenus clarki.*

Female.—Similar in shape and coloration to male. Antennae not plumose. Palpi very short.

Larva (Plate II, fig. E).—Head as in *A. leucocelaenus clarki.* Thorax and abdomen with integument glabrous. Subdorsal abdominal hairs in long strong tufts. Lateral abdominal hairs double or triple on first and second segments, double on third to sixth segments, single on seventh. Lateral comb of eighth segment (Plate II, fig. F) of six scales (eight in paratype) in a single row; individual scales tapering to tip, weakly and evenly fringed. Air-tube short, about two and one-half times as long as wide at the base, slightly tapering beyond the middle. Pecten of some eighteen evenly spaced teeth reaching slightly beyond the middle and followed by a tuft of three short hairs. Anal segment slightly longer than broad, not ringed by the anal saddle, which extends well down the sides of the segment and is fringed on its dorso-posterior angle by short spinules. Dorsal tuft consisting of two branches which originate on a small chitinous plate; dorsal branch long and double, ventral branch single and somewhat longer. Lateral hair double. Ventral brush inserted on a chitinous arch which is preceded by a small, triangular sclerotized plate.

Pupa (Plate II, fig. D).—Trumpet tubular and dark, about three to four times the length of the greatest width. Abdominal chaetotaxy as follows: hair 2 on segment I a short palmate tuft. Hairs 2 and 5 on segments II to VII, short two to five-haired tufts, in each case shorter

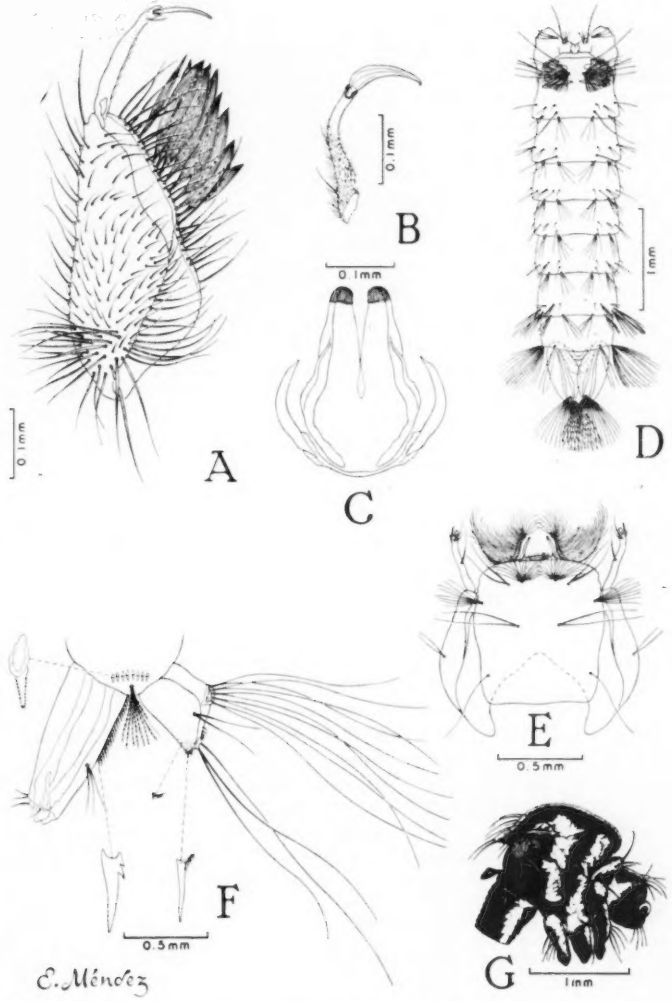
than the segment immediately posterior to the one on which they are inserted. Hair 4 single on segments II to VII, the one on segment II about as long as segment III, those on other segments progressively smaller. Hairs 7 and 8 on segment VII short four- or five-branched tufts. Hair 8 on segment VIII a conspicuous multiple tuft. Paddles narrow, elliptical, with inner borders barely overlapping. Midrib running down the center of a wide clear space, splitting paddle into nearly equal halves. Apical hair a conspicuous multiple tuft about the length of paddle and inserted slightly subapically.

Type Material.—Holotype: Pinned male, with terminalia, larval and pupal skins mounted on two slides. Taken at Feijó, Territorio do Acre, Brazil, on August 4th, 1949. *Allotype:* Pinned female with larval and pupal skins mounted on a slide. Taken at Tarauacá, Territorio do Acre, Brazil, on July 26th, 1949. *Paratype:* Pinned male with terminalia mounted on a slide, and with same data as holotype. All type material collected by the Yellow Fever Service of Brazil and sent to the authors through the courtesy of Dr. Waldemar Antunes and Dr. Henry Kumm. Holotype to be deposited with Dr. John Lane at the Facultade de Higiene e Saude Publica, University of Sao Paulo, Sao Paulo, Brazil. Allotype and paratype at the U. S. National Museum, Washington, D. C.

Aedes (Finlaya) leucotaeniatus Komp

Male.—Coloration as in *A. leucocelaenus clarki* except for silvery white patch on mesepimeron which is angled, taking the shape of an inverted reversed "L" (Plate III, fig. G).

Male terminalia (Plate III, fig. A): Basistyle slightly over twice as long as its greatest width, tapering to the tip. Ventral distal margin with many long lanceolate ribbed nearly sessile scales, and with abundant hairs forming two definite patches, a small one near the apex and a large one which extends from the base, two-thirds the length of the basistyle. Dorsal aspect with many narrow truncate ribbed scales and some stiff long hairs. Dististyle sinuate, between one-third and one-half as long as the basistyle. Inner and outer margins with rows of very fine pile extending for two-thirds of its length. A short seta from a conspicuous base is present on the inner aspect near the apex. Spine moderate, one-third the length of the dististyle, tapering to tip. Claspette (Plate III, fig. B) with long and slender stem slightly curving ventrally and laterally just beyond the middle, clothed nearly to apex with very fine and short hairs and bearing four modified setae as follows: one short straight hair on the basal third of the dorsal margin, arising from a slight prominence on the stem; two very strong and long curved setae on the ventral aspect near the tip of the stem, arising from conspicuous and closely apressed bases and reaching nearly to the tip of the filament; a fourth seta arises from the dorsal margin just below the level of the two strong ventral setae. Filament broad, with flat upper surface, about half as long as the stem and with a retrorse point on the posterodorsal corner and with fine striations all along its surface. Ninth tergite (Plate III, fig. C) a broad chitinous bar with two lateral membranous lobes densely clothed with very fine and short hairs.



Aedes (*Finlaya*) *leucophoebus* n. sp. FIG. A. Style. FIG. B. Claspette. FIG. C. Ninth tergite and tenth sternites. FIG. D. Abdomen of pupa (dorsal view). FIG. E. Head of larva (dorsal view). FIG. F. Terminal segments of larva. FIG. G. Lateral view of adult.

Tenth sternites normal, hooded at tip and terminating in a comb-shaped structure. Mesosome as in *clarki* and *leucophoebus*.

Larva (Plate III, fig. E).—Head as in *clarki* and *leucophoebus*, except for hairs "B" and "C" which are single instead of double. Integument of body glabrous. Lateral abdominal hairs triple on segments I and II, double on segments III to VI and single or double on segment VII. Subdorsal abdominal hairs in long tufts. Lateral comb of eighth segment (Plate III, fig. F) of from six to eight scales in a single row. Individual scales tapering to an obtuse point and weakly fringed. Air tube slightly bulging at the middle and then tapering to tip, three times as long as its basal width. Pecten of some fifteen to twenty closely apressed evenly spaced teeth reaching slightly beyond the basal third of tube, and followed by a tuft of two long hairs inserted at about middle of tube. Anal segment longer than wide. Anal saddle not ringing the segment but reaching well down the sides of it, fringed on its posterodorsal angle with a patch of spinules. Dorsal tuft arising in two branches from a small chitinous plate, dorsal branch four-haired, ventral branch single. Lateral anal hair double, long. Ventral brush arising from a chitinous arch which is preceded by a small, triangular sclerotized plate.

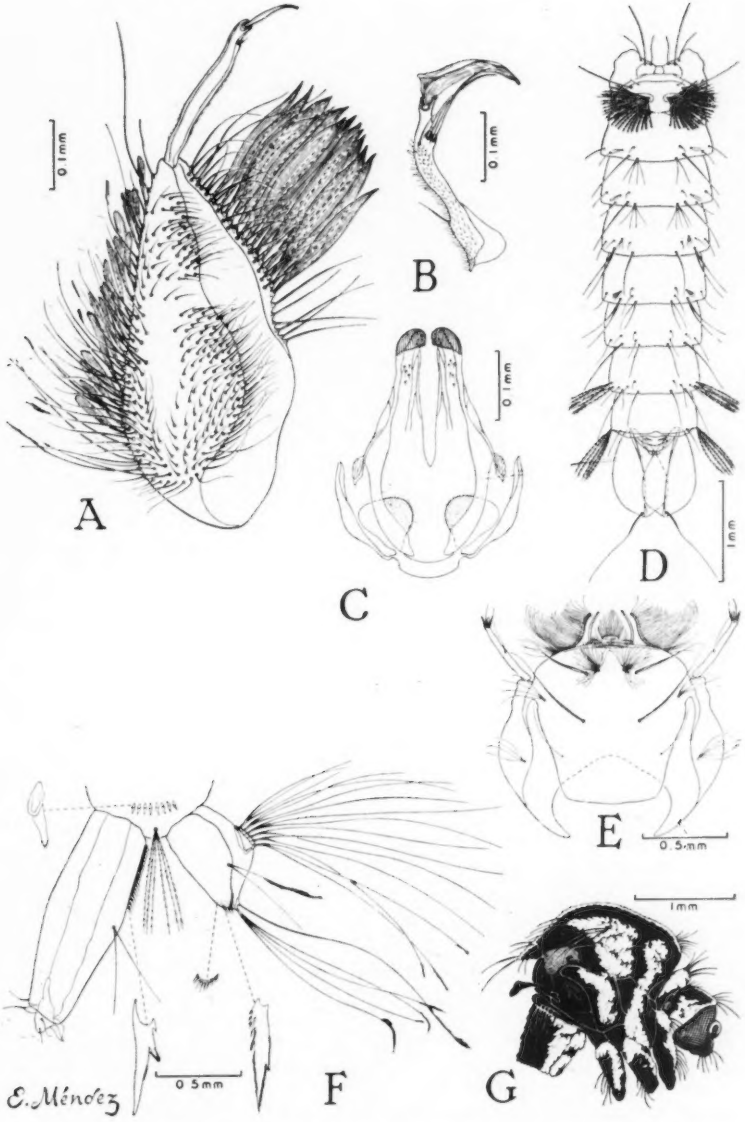
Pupa (Plate III, fig. D).—Trumpets short, barely three times as long as their greatest width. Dorsal abdominal chaetotaxy as follows: hair 2 of segment I a large, multiple palmate tuft. On segments II and III this hair is two- to four-branched and short, being approximately half the length of the succeeding segment; on segments IV to VII it is single or double and slightly shorter than the length of segment immediately following. Hair 5 single on segments II and III, single or double on segments IV to VII, slightly longer than the length of the segment immediately following the one on which it is inserted. Hair 8 on segment VIII a multiple conspicuous frayed tuft. Paddles ovoid and fairly long, being as long as the total length of segments VII and VIII. Midrib narrow but quite pronounced, splitting the paddle into two nearly equal halves. Apical hair single, about the length of the paddle and inserted slightly subapically.

Material Examined.—Eighteen males and twenty-four females with associated larval and pupal skins, taken at La Victoria, Province of Panama; Buena Vista, Province of Colon; Cerro Campana, Province of Panama; Tucue, Province of Cocle and Bijao, Province of Chiriqui: all in the Republic of Panama.

TAXONOMIC DISCUSSION

As was pointed out in the introduction, there appear to be at least five forms in the *Aedes leucocelaenus* complex, four of which are discussed in this paper, namely: *Aedes* (*Finlaya*) *leucocelaenus leucocelaenus* Dyar and Shannon, 1924; *Aedes* (*Finlaya*) *leucocelaenus clarki* n. ssp.; *Aedes* (*Finlaya*) *leucotaeniatus* Komp, 1938; *Aedes* (*Finlaya*) *leucophoebus* n. sp., which may be separated from each other by the characters described below.

Adult.—Adults of *leucotaeniatus* and *leucocelaenus clarki* may be separated with relative ease by the white marking on the mesepimeron. In *leucotaeniatus* this marking takes the form of an inverted reversed



Aedes (*Finlaya*) *leucotaeniatus* Komp. FIG. A. Style. FIG. B. Claspette. FIG. C. Ninth tergite and tenth sternites. FIG. D. Abdomen of pupa (dorsal view). FIG. E. Head of larva (dorsal view). FIG. F. Terminal segments of larva. FIG. G. Lateral view of adult.

"L" (Plate III, fig. G) while in *leucocelaenus clarki* it is bar-shaped (Plate I, fig. G), occasionally showing a small spur pointing back toward the dorsoposterior angle of the sclerite, but never approaching the form of the inverted reversed "L" which we have noted for *leucotaeniatus*. In the field these two species can be easily separated by size alone, as *leucotaeniatus* is a large species, the average specimen being twice as large as the average specimen of *leucocelaenus clarki*. We have not had an adequate series of *leucocelaenus leucocelaenus* or *leucophoebus* to judge possible variations in the shape of the white mesepimeral marking, but in the specimens examined of both species, the shape of this marking appears intermediate between the conditions found in *leucotaeniatus* and *leucocelaenus clarki*, but possibly closer to *leucotaeniatus*. In size *leucophoebus* and *leucocelaenus leucocelaenus* also appear to be intermediate between the other two members of the complex.

Male terminalia.—We have not been able to find any characters of the male terminalia to separate with certainty *leucocelaenus clarki* from *leucocelaenus leucocelaenus*. The number of setae on the stem of the claspette seems to separate the great majority of the specimens, but it is a variable character. We have mounted and studied the terminalia of thirty-seven specimens of *leucocelaenus clarki* from Panama; of these, thirty-four have but three outstanding setae on the stem of the claspette, two specimens have four setae on one claspette and three on the other, while one specimen has four setae on both claspettes. Of the nine terminalia studied from Rio de Janeiro and Sao Paulo, Brazil, seven show four setae on both claspettes, while two appear with four setae on one claspette and three on the other, these two specimens being from Rio de Janeiro.

The two subspecies of *leucocelaenus* may be separated from *leucophoebus* by the following characters. In *leucocelaenus* the blade of the claspette is about the size of the stem, while in *leucophoebus* it is much shorter than the stem. The shape of the blade also differs in these species as shown in the figures. In *leucocelaenus* the stem of the claspette has a single curvature while in *leucophoebus* it curves laterally and ventrally. In *leucocelaenus* there are three or four outstanding setae on the stem of the claspette while in *leucophoebus* there are only two of these setae. The species may be also separated on the morphology of the ninth tergite; in *leucocelaenus* the ninth tergite is made up of two lateral thin, broad plates joined in the center by a short and thin membrane which tends to tear during dissection, while in *leucophoebus* the two lateral plates are joined by a rather long sclerotized bar.

Aedes leucotaeniatus may be easily separated from the other members of the complex on male terminalia characters as shown in the figures. The main characters for separation are to be found in the shape and chaetotaxy of the claspette. There are also present in *leucotaeniatus* two lateral hairy, membranous lobes on the ninth tergite, as noted by Komp (*loc. cit.*), which are absent in the other species.

Larva.—The larva of *leucocelaenus clarki* may easily be separated from the other members of the complex by the relative length of the air-tube. In *leucocelaenus clarki* the tube is long, being four times as long as its basal width, while in the other known members of the complex the proportion of length to basal width is three to one at most. Larvae

of *leucocelaenus clarki* can further be separated from those of *leucocelaenus leucocelaenus* and of *leucophoebus* by the branching of the dorsal anal hair. In *clarki* this hair has from four to eight branches while in *leucocelaenus leucocelaenus* and *leucophoebus* it only has two or three ramifications.

The larva of *leucophoebus* differs from that of *leucocelaenus lecocelaenus* and of *lecotaeniatus* by the following characters. In *leucophoebus* the air tube is about two and one-half times as long as its basal width, while in *l. leucocelaenus* and *leucotaeniatus* the proportion is three to one. In *leucophoebus* the ventral tuft of the air-tube is short and three-haired, being much shorter than the length of the anal segment, while in *l. leucocelaenus* and in *leucotaeniatus* this tuft is longer than the anal segment and has two branches. Finally the dorsal anal tuft has two branches in *leucophoebus*, three in *l. leucocelaenus* and four in *leucotaeniatus*.

Pupa.—*Aedes leucocelaenus clarki* n. ssp. may be separated from *leucocelaenus leucocelaenus*, *leucophoebus* and *leucotaeniatus* by the shape of the paddles which in *l. clarki* are fan-shaped and markedly asymmetrical, showing a concave indentation at the point where the apical hair is inserted, while in the other three members of the complex the paddles are elliptical or ovoid in shape and barely asymmetrical. *A. leucocelaenus clarki* also differs in that hair 2 of segment I is represented by a long four to six-haired tuft pointing forward over the cephalothorax. This hair tuft is longer than the sum of the lengths of segments II and III, while in the other species it is the usual palmate tuft.

As pointed out in the introduction, pupae of *leucocelaenus* from Rio de Janeiro show various degrees of intergradation between typical *leucocelaenus* from Sao Paulo and typical *clarki* from Panama, particularly in the shape of the paddles and in hair 2 of segment I.

Aedes leucophoebus may be differentiated from all other members of the complex by the shape of the paddles which are small and elliptical and by the apical hair which is a short, multiple tuft.

The pupae of typical *l. leucocelaenus* and of *leucotaeniatus* appear very close and the only reliable character which we have found to separate them with certainty is the pigmentation of the integument of abdominal segments II and III. In *leucotaeniatus* these segments are evenly colored, while in *l. leucocelaenus* they appear with a pigmented area of varying size and intensity extending lengthwise along the middle of these segments.

LITERATURE CITED

Dyar, Harrison G. 1928. The mosquitoes of the Americas. Carnegie Inst. Washington, Pub. no. 387: 1–616, pls. i-cxxii.

Dyar, Harrison G., and **R. C. Shannon.** 1924. The subfamilies, tribes and genera of American Culicidae. Jour. Washington Acad. Sci., 14: 472–486.

Galindo, Pedro, Harold Trapido, and **S. J. Carpenter.** 1950. Observations on diurnal forest mosquitoes in relation to sylvan yellow fever in Panama. (Studies on forest mosquitoes of Panama. II.) Amer. Jour. Trop Med., 30(4): 533–574.

Hopkins, G. H. E. 1936. Mosquitoes of the Ethiopian region. I. Larval bionomics of mosquitoes and taxonomy of culicine larvae. Pp. viii+250, 158 figs. Brit. Mus. (Nat. Hist.).

Knight, K. L., and **R. W. Chamberlain.** 1948. A new nomenclature for the chaetotaxy of the mosquito pupae, based on a comparative study of the genera. (Diptera, Culicidae). Proc. Helminth. Soc. Washington, 15: 1–18.

Komp, W. H. W. 1938. *Aedes leucotaeniatus*, a new species of *Aedes* allied to *A. leucocelaenus* D. & S.; and descriptions of the male and larva of *A. leucocelaenus* D. & S. (Diptera, Culicidae). Proc. Ent. Soc. Washington, 40(8): 260–266.

Lane, John. 1939. Catalogo dos mosquitos neotropicos. Bol. Biol., Sao Paulo. Ser. Monogr. I. Pp. xiv+218.

Lutz, A. 1904. *In* Bourroul, C., Mosquitos do Brasil. Faculdade de Medicina da Bahia, These de Doutoramento. Bahia, Brasil.

THE RECENT CLIMATIC FLUCTUATION IN FINLAND AND ITS CONSEQUENCES. A symposium edited by ILMARI HUSTICH for the Geographical Society of Finland. Fennia, 75. 128 pp. Helsinki, 1952.

In recent years much attention has been directed by Finnish scientists to the marked amelioration of the climate since the turn of the century and particularly since the early 1930's. These changes and their manifold effects are the subject of this interesting symposium. The climatologic and meteorologic changes themselves are summarized briefly by J. Keränen, director of the Central Meteorological Institute. The milder winters are attributed to shifts in the Azores high pressure area and the Icelandic low pressure mass which allow an enhanced northward flow of warm air. The warmer summer temperatures are attributed to increased periods of sunshine and an increase in warm air currents from the continental land masses to the south and east. It is possible that the general clearing of the earth's atmosphere of fine volcanic material has been a basic factor. Among the consequences of these changes in climate are changes in the degree and pattern of the freezing of the Baltic Sea and the ramifications thereof, changes in foliation and flowering time of many species of plants, changes in distributions of many species of plants, changes in the carbon dioxide content of the atmosphere (cause or effect?), changes in salinity of Finnish coastal waters and its effect on the distribution of aquatic animals, changes in the distribution and abundance of many species of birds and mammals, and changes in the success and yield of certain agricultural crops. Of particular interest to entomologists is "The significance for insects of climatic changes" (pp. 60–68) by Adolf Fr. Nordman and the remarks of Harry Krogerus (pp. 58–59). Data on the changes in insect fauna are quite fragmentary although nevertheless interesting. There has been an obvious northward expansion of the ranges of several species of strong-flying macrolepidoptera and an increase in population of rare southern species.

—DONALD S. FARNER.

BIOLOGICAL OBSERVATIONS ON PARASITES OF THE BLACK SCALE[1]

STANLEY E. FLANDERS[2]
Division of Biological Control, University of California
Citrus Experiment Station, Riverside

During the past 50 years, 34 species of Hymenoptera parasitic on the black scale, *Saissetia oleae* (Bern.), have been introduced into California. These introductions represent a more or less continuous effort on the part of California agriculture to bring this scale insect under biological control. This goal has in large measure been attained through the introduction and establishment of *Metaphycus helvolus* (Comp.). In a few localities and in certain years *M. helvolus* is not effective because of prolonged periods of low winter temperatures. Such low-temperature periods reduce the voltinism of the parasite, the smaller number of parasite generations occurring, to one generation of the host, preventing biological control. The work of introducing additional parasites of black scale therefore is being continued.

Since 1935, the writer has propagated and studied 25 species of black scale parasites. The following observations are derived from this study.

BLACK SCALE STAGES AND THEIR PARASITES

In the laboratory the black scale may have six generations annually, but in the citrus orchards of California it is limited to two generations in humid areas and one in dry areas. Each generation of black scale consists of five stages: namely, the egg stage, the first instar, the second instar, and the third instar, which is made up of the nongravid and gravid stages. When grown on potato sprouts in the laboratory, at temperatures between 70° and 75° F., the incubation period for the egg is about two weeks, the eggs occupying an egg chamber (ovisac) formed by the retracted ventral surface of the parental body. Development for the first instar requires about two and one-half weeks, for the second instar about two and one-half weeks, and for the third instar about three and one-half weeks.

Each stage of the black scale except the early part of the first instar may serve as a primary host for one or more of at least 29 species of parasitic Hymenoptera. Third-instar black scale, or scales in the ovisac stage, may serve as secondary or tertiary hosts. These species are listed below under the host stage that is first attacked. Unless other-

[1]Paper No. 735, University of California Citrus Experiment Station, Riverside, California.

[2]Professor of Biological Control and Entomologist in the Experiment Station.

wise stated, all species are thought to be indigenous to Africa. The asterisk (*) designates species established in California.

Group I. First-Instar Black Scale as a Primary Host
Coccophagus basalis Comp.
**Coccophagus ochraceus* How. Male, only, ectoparasitic.
Encyrtus sp., near *infelix*. Host grows nearly to maturity before being destroyed.

Group II. Second-Instar Black Scale as a Primary Host
Aneristus ceroplastae How.
**Coccophagus cowperi* Gir.
**Coccophagus lycimnia* (Walk.). United States.
**Coccophagus pulvinariae* Comp.
**Coccophagus trifasciatus* Comp.
Diversinervus smithi Comp. Host grows to maturity.
Euxanthellus sp.
**Metaphycus helvolus* (Comp.).
**Metaphycus luteolus* (Timb.). Native habitat unknown.
**Metaphycus stanleyi* Comp.

Group III. Nongravid Stage of Third-Instar Black Scale as a Primary Host
Coccophagus caridei (Brèthes). South America.
**Coccophagus capensis* Comp.
**Coccophagus rusti* Comp.
**Coccophagus scutellaris* (Dal.). Native habitat unknown.
Coccophagus yoshidae Nak. Japan.
Encyrtus fuliginosus Comp.
**Metaphycus lounsburyi* (How.).

Group IV. Gravid Stage of Third-Instar Black Scale as a Primary Host
Microterys saissetiae Comp.
Coccidoxenus niloticus Comp.

Group V. Ovisac Stage of Black Scale as a Primary Host
Anysis saissetiae (Ashm.). Asia.
Aphobetoideus comperei Ash. Australia.
Lecaniobius cockerelli Ashm. West Indies.
**Lecanoibius utilis* Comp.
Mesopeltis sp.
**Scutellista cyanea* Motsch.
**Tomocera californica* How. Australia.

Group VI. Either Third Instar of Black Scale or Its Ovisac Stage as a Secondary Host
Baeoanusia oleae (Silv.).
**Cheiloneurus noxius* Comp. United States.
**Eupelmus inyoensis* Gir. United States.
**Eusemion californicum* Comp. United States.
**Quaylea whitteri* (Gir.). Australia.
**Tetrastichus blepyri* Ashm. United States.
(*Metaphycus helvolus* has no hyperparasites that affect its value in controlling black scale.)

Group VII. Either Third-Instar or Black Scale or Its Ovisac Stage as a Tertiary Host
Myiocnema comperei Ashm. Australia.

DEVELOPMENTAL RELATIONS

Observations on black scale parasites during their propagation in the laboratory and after their release in the field revealed the following relations

A considerable variation occurs in the life cycles of individuals of a single parasite species at the same temperature, particularly among the primary forms. Some parasites complete their development in the

host stage attacked; others continue into the later stages of the host. The emergence of the adult parasite from its host occurs about a day after it casts the pupal exuvia.

The parasites of the black scale are both solitary and gregarious in their development. With certain species, only one individual can complete its development in an individual host; with others, one or more individuals of a species may complete their development in an individual host, the number completing development being determined by the amount of food supplied by the host. Solitary parasitism is obligatory in the first case, and facultative in the second. The solitary relationship is obligatory with *Coccophagus trifasciatus* because the first parasite larva has an immunizing effect, and with *C. ochraceus* because oviposition does not occur in hosts large enough to support more than one parasite larva. *Metaphycus lounsburyi* is either solitary or gregarious in its development. The size of the host is the determining factor, since the parasite has the habit of depositing more than one egg in a host. *Diversinervus smithi* is obligatorily gregarious, since the host's contents exceed the food requirements of one parasite, and the presence of more than one parasite is needed to consume all the host's contents and thus provide conditions suitable for the pupation of the parasites.

Metaphycus helvolus is limited in its oviposition and development to small, immature black scale; *Coccidoxenus niloticus* is limited to fully mature black scale. *Coccophagus trifasciatus*, on the other hand, not being limited to either the immature host or the mature host, develops as a solitary parasite in all stages except the first. Uniquely, the adults of this parasite are quite constant in size, regardless of the size of the host, since in the parasitized host the amount of food available to the parasite nearly always exceeds its needs. Solitary species usually increases in size with increase in size of the host; gregarious species tend to decrease in size as the size of the host stages attacked increases.

The male of *Coccophagus trifasciatus*, unlike most species of this genus, is rarely if ever hyperparasitic on its own species. The fact that the female reaches maturity before it has consumed all the body contents of its host precludes the hatching of any male egg present. The male, therefore, must parasitize a parasitic species that consumes practically all the fluid contents of the scale. Not all such parasitic species, however, are suitable for male development. Species of the genus *Coccophagus* having habits similar to those of *C. lycimnia* are the only hosts known to be suitable for the development of males of *C. trifasciatus*.

The development of *Diversinervus smithi* is completely synchronized with that of its host, regardless of the time of oviposition, since the parasite remains as a first-stage larvae until the host is fully gravid. The development of the black scale is unaffected by the presence of the larva of this parasite, except that oviposition is inhibited. After the parasites break out of the host ganglion (fig. 1), they develop very rapidly. The larvae of *D. smithi*, unlike those of most of the other parasites, do not form cocoons.

With *Encyrtus* sp. (near *infelix*), the egg is deposited in very young black scale, and the parasite matures when the scale is near maturity.

The full-fed larvae of *Lecaniobius utilis* may undergo an over-wintering diapause of several months when both host and temperature conditions are constant. Most of the other black scale parasites develop so rapidly that the parasitized host shows little if any development after the parasite egg is deposited within it. There may be, however, a noticeable development of the host while inhabited by the parasite larvae of *Coccophagus capensis* and *Encyrtus fuliginosus*. Black scale, if mature, may reproduce although containing the pupa of *C. trifasciatus*. Young scale in which *C. trifasciatus* larvae have begun to construct cocoons take on the appearance of very small mature scales. Immature black scales, when parasitized by *C. trifasciatus*, may shrink slightly, so that the portion occupied by the parasite's cocoon is indicated by a bulge.

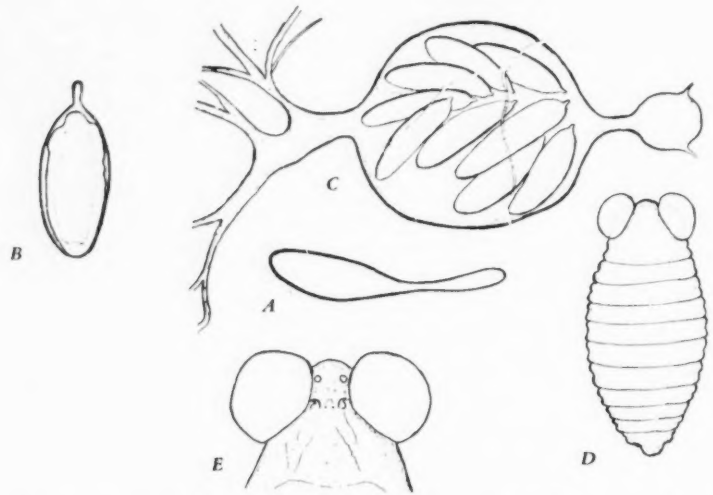


FIG. 1. Eggs and first-stage larva of *Diversinervus smithi* Comp. A. Ovarian egg. B. Deposited egg containing well-developed embryo. C. Composite subesophageal ganglion of black scale containing 10 eggs of *D. Smithi*. D. First-instar larva hatched after 10-day incubation period at 80° F. E. Ventral view of head of larva, showing cephalic vesicles. (The first-stage larvae remain in the composite suboesophageal ganglion of the scale until the scale is gravid and turgid with eggs.)

The oviposition of a black scale is not affected by the presence of larvae feeding only on the eggs in the ovisac. A black scale inhabited by a larva of *Coccophagus capensis* may produce enough eggs to enable a larva of *Scutellista cyanea* to mature, the scale remaining alive until it contains the adult of *C. capensis* ready to emerge.

The adults of egg-feeding species such as *Tomocera californica*, *Scutellista cyanea*, *Lecaniobius utilis*, and *Mesopeltis* sp. insert their ovipositors under the parent scale, never penetrating its body wall.

With few exceptions, all the other parasitic species, whether primary, secondary, or tertiary, insert the ovipositor through the body wall. In most cases this is done either dorsally or ventrally. *Metaphycus stanleyi*, however, oviposits only in the very narrow side of the scale, in line with the marginal hairs.

Metaphycus lounsburyi and *Coccophagus trifasciatus* thrust the ovipositor through the soft ventral derm of the scale. *Quaylea whittieri* does likewise in its search for the larvae of *M. lounsburyi*. Most of the other species studied drill through the thicker dorsum of the host, the time required in drilling depending on the structure of the ovipositor and the toughness of the host's derm. *C. ochraceus* is unique in its facultative egg deposition: When the spermathecal gland is more or less turgid, oviposition takes place through the dorsum of the host, and a fertilized egg is deposited; whereas when the gland lacks secretions, the ovipositor is simply inserted under the host, and an unfertilized egg is deposited. When the female of *C. ochraceus* is prevented from depositing eggs under its host, all deposited eggs are fertilized.

In certain species, such as *Metaphycus helvolus*, *M. luteolus*, *Tetrastichus blepyri*, and *Coccophagus ochraceus*, the ovipositor may be used, at times, solely for the purpose of enabling the female to feed on the body fluids of the host. The adults of such species are long-lived and have relatively few ripe eggs in the ovaries at any one time. These eggs, if not deposited within a few hours, disappear through oösorption.

With three exceptions, the females in all of the species named appear to develop only from fertilized eggs; that is, reproduction is biparental. The three exceptions are the uniparental species *Encyrtus fuliginosus*, *Tomocera californica*, and *Lecaniobius cockerelli*. In these species the female, like the normal hymenopterous male, develops from an unfertilized egg.

All the black scale parasites within a given habitat may compete with one another. Competition may be intrinsic (within the host) or extrinsic (external to the host). Such parasites as *Mesopeltis* sp., *Diversinervus smithi*, and *Coccophagus ochraceus* are not intrinsic competitors, since each attacks stages of the scale that usually are not attacked by the others. They may be, however, extrinsic competitors, since each may destroy scale that otherwise might be attacked by the others, or that might produce progeny that might be attacked.

Mesopeltis, when competing with *Scutellista cyanea* in the insectary, is intrinsically inferior. These species do not appear to be competitors under field conditions, since they frequent different environments.

Relations in intrinsic competition may vary greatly. Scales that are parasitized by *Diversinervus smithi* and then by *Coccophagus rusti* always yield *C. rusti*. If *Diversinervus* is followed by *Microterys*, however, *Diversinervus* is able to mature in part of the scales.

The long life cycle of *Diversinervus* apparently is a handicap in competition with species having short life cycles. The fact, however, that the first stage of *Diversinervus* remains so long within the host ganglion of the scale greatly limits the period of vulnerability to hyperparasitism. In addition, the larvae and pupae of *Diversinervus* are to a large extent immune to secondary endoparasitism. Large ectoparasitic hyperparasites, however, such as *Eupelmus inyoensis*, may destroy all

the larvae or pupae within a scale. The ectoparasitic males of *Coccophagus pulvinariae* also can mature on *Diversinervus*.

Certain primary parasites of black scale are unsuitable for the development of the hyperparasitic male of *Coccophagus rusti*. When deposited in *Diversinervus smithi*, the eggs of *C. rusti* remain unhatched

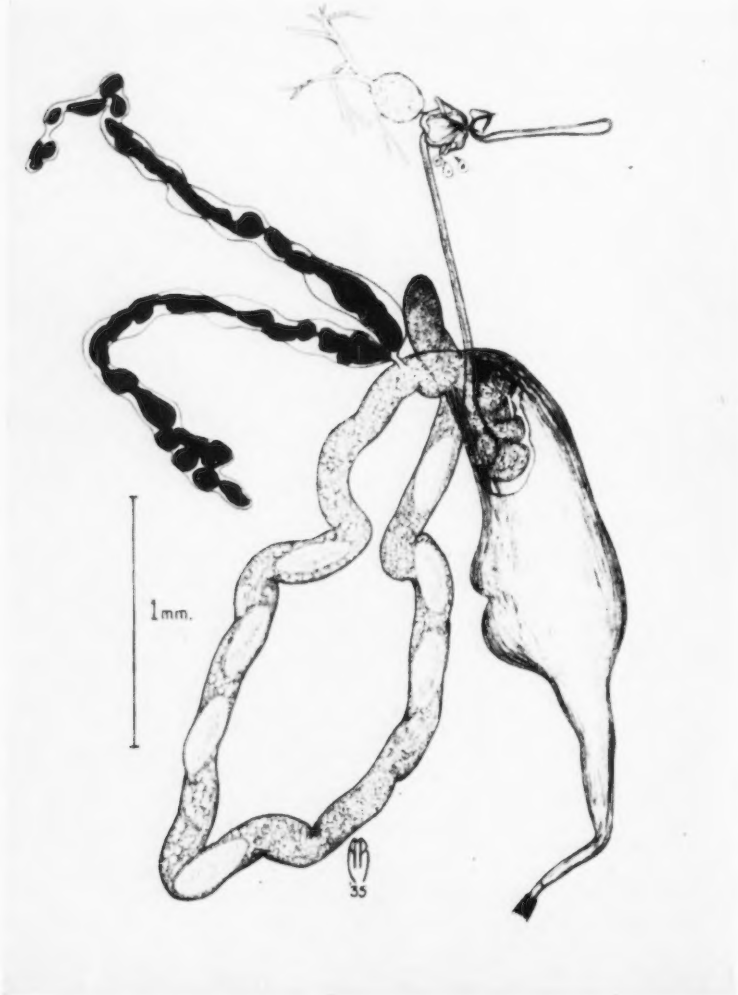


FIG. 2. Digestive system of the black scale *Saissetia oleae* showing seven eggs of *Coccophagus caridei* located in the midgut extension. Note the composite suboesophageal ganglion (sub-brain).

and are melanized. In the larvae of *Encyrtus fuliginosus* the eggs hatch but the larvae die.

Unfertilized eggs may be deposited in the body fluids of black scale by mated females of *Coccophagus rusti*. These eggs hatch but are unable to develop. In one instance, a first-instar male larva was observed unsuccessfully attempting to feed ectoparasitically on a female larva which was feeding on the blood of a black scale.

Mated females of *Coccophagus caridei* when ovipositing in the immature stages of black scale place their eggs in the lumen of the midgut (fig. 2). These eggs rarely, if ever, hatch. When oviposition occurs on mature black scale the eggs for the most part are placed free within the body cavity outside of the midgut. These eggs, immersed in the blood of the scale, usually hatch and become adults.

Under field conditions, where the development of the black scale is greatly prolonged, the larvae of *Diversinervus* may remain in the subbrain of the scale and ultimately die there. Presumably, such host scales reach maturity.

SUMMARY

Certain relations of more than 25 species of hymenopterous parasites of the black scale, to this host and to each other, are reported. These species are listed according to the host stage attacked.

REFERENCES

Compere, Harold. 1925. New chalcidoid (hymenopterous) parasites and hyperparasites of the black scale, *Saissetia oleae* Bernard. Univ. California Pubs. Ent., 3: 295–326.

1931a. A revision of the genus *Diversinervus* Silvestri, encyrtid parasites of coccids (Hymenoptera). Univ. California Pubs. Ent., 5: 233–245.

1931b. A discussion of the parasites of *Saissetia oleae* (Bern.) Collected in Eritrea. Univ. California Pubs. Ent., 5: 247–255.

1931c. The African species of *Baeoanusia*, an encyrtid genus of hyperparasites (Hymenoptera). Univ. California Pubs. Ent., 5: 257–264.

1931d. A revision of the species of *Coccophagus*, a genus of hymenopterous coccid-inhabiting parasites. Proc. U. S. Natl. Mus., 78: 1–132.

1936. Notes on the classification of the Aphelinidae, with descriptions of new species. Univ. California Pubs. Ent., 6: 277–322.

1939. The insect enemies of the black scale, *Saissetia oleae* (Bern.) in South America. Univ. California Pubs. Ent., 7: 75–90. (Including biological notes by S. E. Flanders.)

1940. Parasites of the black scale, *Saissetia oleae*, in Africa. Hilgardia 13(7): 387–425. (Including biological notes by S. E. Flanders.)

Flanders, Stanley E. 1939a. A black scale parasite with promising qualities. Jour. Econ. Ent., 32: 152.

1939b. The propagation and introduction of *Coccophagus heteropneusticus* Comp., a parasite of lecaniine scale insects. Jour. Econ. Ent., 32: 888–890.

1942a. Propagation of black scale on potato sprouts. Jour. Econ. Ent., 35: 687–689.

1942b. *Metaphycus helvolus*, an encyrtid parasite of the black scale. Jour. Econ. Ent., 35: 690–698.

Smith, Harry S. 1942. Biological control of the black scale. Calif. Citrog., 27: 266, 290–291.

Smith, Harry S., and **Stanley E. Flanders.** 1949. Recent introductions of entomophagous insects into California. Jour. Econ. Ent., 42: 995.

OVIPOSITION AND HATCHING IN SOME SPECIES OF TABANIDAE

(Diptera)[1]

NAWAB H. KAHN
Department of Zoology, Muslim University
Aligarh, India

The eggs of Tabanidae are laid in masses, mostly in the vicinity of water. There is, however, a great variation in the selection of oviposition sites. Some species almost always deposit their eggs on particular plant species, while others do not show any affinity for specific plants. *Tabanus stygius* Say always oviposits on the upper surface of the *Sagittaria* leaves and as Hine (1903) points out, "So closely is this habit followed that a hundred masses are found thus located to one placed otherwise." On the other hand, *Chrysops callida* O. S. observed by the author deposits its eggs on several species of grass plants and wild iris equally well.

Patton and Cragg (1913) point out that the selection of oviposition sites has a very definite correlation with the future fate of the larvae. *Tabanus albimedius* Walk., *Tabanus speciosus* Ricardo, and the like, whose larvae are bigger and can swim well, lay their eggs over deep water, while the larvae of smaller species like *Tabanus ditaeniatus* Macq., being devoid of air sacs and thus being weak swimmers, are liable to die if dropped in deep water. Such species have invariably been found to deposit their eggs on grass blades over shallow streams and small ponds, but never over deep water.

Cameron (1926) has, however, obtained egg masses from newly emerged females of *Chrysops fulvaster* O. S. and *Tabanus reinwardtii* Wiedemann in glass jars under laboratory conditions.

The number of eggs per mass is variable and differs with individuals and species. According to Stone (1930) the number of eggs in individual masses of Tabanidae varies between 100 and 800. The writer made counts of ten egg masses of *C. callida* which varied between 107 and 306, with an average of 240.5 eggs per mass. Two egg masses of *Tabanus superjumentarius* Whitney laid in the laboratory contained 96 and 128 eggs, and those of *Tabanus lineola* Fabr. 110 and 216. It was noticed in the case of *T. lineola* that the size of the egg masses laid in the laboratory was definitely smaller than those laid in the field. This may have been due to dietary deficiency. It has been suggested by many workers that a blood meal is necessary for oviposition. In all cases the eggs laid in the laboratory were deposited several days after a blood meal, during which time the females were offered honey solution. It may be that the lack of a blood meal resulted in the reduced size of the egg masses.

The coloration of eggs presents an interesting problem. All the egg masses of *C. callida* observed when freshly laid were white. The color

[1]Part of a doctorate thesis presented at the University of Massachusetts. The author wishes to express his sincerest thanks to Professor Harvey L. Sweetman, under whose kind direction this work was undertaken.

changed to lustrous black in four to five hours, under laboratory conditions, and in one to two hours in the field when exposed to sunlight. However, egg masses of *T. lineola* and *T. superjumentarius* deposited in the laboratory retained the original whitish brown and shiny white color until hatched. These observations, in the case of *C. callida* are strongly suggestive that the change of color is stimulated by higher field temperature and some fraction of light absent in the laboratory, being much more rapid in bright sunlight than under laboratory conditions.

The eggs are cylindrical in shape, tapering toward the ends. The length varies between 1 and 2.7 mm. and the diameter between 0.2 and 0.4 mm. (Stone, 1930). Generally the species of *Tabanus* lay their eggs in several layers while those of *Chrysops* deposit only single layers. However, a few species, as *C. celer* O. S., lay several tiers of eggs.

Considerable time is required to deposit an egg mass. In two laboratory observations *T. superjumentarius* took 56 and 58 minutes to deposit egg masses. Females of *C. callida* observed in the field utilized 56 and 68 minutes for oviposition. Three times the females of this species were seen to fly away after 20 to 36 minutes of laying eggs, probably because of some disturbance. The incomplete egg masses deposited by such females were smaller in size in proportion to the time utilized. The flies do not return to complete such masses. Presumably oviposition is completed somewhere else.

Not all the eggs or egg masses hatch, for various reasons. They may be parasitized by other insects, unfertilized or attacked by microorganisms.

The incubation period is variable, largely as a response to temperature. Stone (1930) noted that the egg stage was prolonged in cool and cloudy weather, and Segal (1936) concurs in this opinion.

EFFECT OF TEMPERATURE ON HATCHING OF EGGS OF C. CALLIDA O. S.

Egg masses of *C. calida*, collected shortly after being laid in the field were incubated at three temperatures. Each leaf containing an egg mass was fastened to a cork with a pin and hung in a bottle containing water, as shown in fig. 1. The larvae after hatching fell into the water. This technique was very useful for collecting young larvae, as they survived in the water for more than 24 hours. The results obtained are presented in the table below.

DURATION OF THE EGG STAGE OF *Chrysops callida* AT VARIOUS TEMPERATURES

TEMPERATURE DEGREES C.	DAYS TO HATCH									AVERAGE DURATION
	3	4	5	6	7	8	9	10	11	
22	0	0	0	0	3	1	2	2	2	8.9
27	1	2	6	0	0	1	0	0	0	4.9
32	2	5	2	1	0	0	0	0	0	4.2

It is evident that the incubation period decreased with an increase in temperature from 22° C to 32° C. This suggests the probability that under field conditions eggs exposed to direct sunlight, because of increased temperature, would hatch sooner than those in the shade.

The threshold temperature for the development of eggs, as determined by Krogh's curve (Chapman, 1931), lies at 15.6° C. During the course of the present work it was also noticed that somewhat greater numbers of egg masses hatched at 27° C than at 22° C.

FIG. 1. Egg bearing leaves pinned to corks in bottles.

CONCLUSIONS

The eggs of Tabanidae are laid in masses, mostly in the vicinity of water. The selection of oviposition sites differs with different species, some laying eggs on particular plants, while others showing no special preference. All the egg masses of the three species, *T. lineola*, *T. atratus*, and *C. callida*, collected were laid in the immediate vicinity of water. The number of eggs per mass varied between 107 and 306, 96 and 128, and 110 and 216, with *C. callida*, *T. superjumentarius*, and *T. lineola* respectively. Temperature has a marked effect on the hatching of the egg masses of *C. callida*. The average duration for the incubation perior was 8.9 days at 22° C, 4.9 at 27° C and 4.2 at 32° C with a threshold at 15.6° C.

REFERENCES

Cameron, A. E. 1926. Bionomics of the Tabanidae (Diptera) of Canadian prairie. Bull. Ent. Res., 17: 1–42.

Chapman, R. N. 1931. Animal ecology with special reference to insects. McGraw-Hill Book Company, Inc., New York and London, p. 48.

Hine, J. S. 1903. Tabanidae of Ohio. Ohio Acad. Sci. special paper, 5: 1–57.

Patton, W. S., and **F. W. Cragg.** 1913. A textbook of medical entomology. Christian Literature Society for India, pp. 271–305.

Segal, B. 1936. Synopsis of the Tabanidae of New York, their biology and taxonomy. Jour. New York Ent. Soc., 44(1): 51–78, 125–154.

Stone, A. 1930. The bionomics of some Tabanidae (Diptera). Ann. Ent. Soc. Amer., 23(2): 261–304.

SOME AMERICAN POLYDESMID MILLIPEDS IN THE COLLECTION OF THE CHICAGO MUSEUM OF NATURAL HISTORY

RALPH V. CHAMBERLIN

In the present paper are given records and descriptions of some American millipeds of the order Polydesmida forming part of the diplopod collection of the Chicago Museum of Natural History. The other orders will be reported upon separately. The material of this rich collection came mostly from the southeastern United States, Mexico, and Central America, in the last mentioned area Guatemala being especially well represented. Several interesting species were taken at Cali in western Colombia. This collection has been brought together chiefly through the special interest and sponsorship of Dr. Karl P. Schmidt, director of the Chicago Museum, who, it will be noted, personally collected a large proportion of the material here reported upon. Most of the remaining specimens were collected by Henry Dybas of the same institution. The large proportion of new forms represented indicates that little more than a beginning has been made in bringing to light the undoubtedly very rich myriopod fauna of Middle America.

Family **Sphaeriodesmidae**

Sphaeriodesmus bukowinus, new species

Figs. 1, 2

The preserved specimens reveal nothing as to the original color, presenting merely the testaceous hue usual after long preservation in alcohol.

Body narrowing a little from the fifth segment caudad, more strongly so over the last four or five segments.

Collum fusiform, the lateral ends narrowly rounded; equalling or slightly exceeding the head in width.

Anterior rim of segments 2 to 4 sharply raised. Keels of fourth segment with anterior margin convex, anterior corner of keel rounded off; the posterior margin slightly concave. Fifth tergite distinctly wider than the fourth; keels but little narrowing laterad, both anterior and posterior corners rounded, the lateral margin moderately convex. The immediately following keels strongly narrowed laterad, with the ends rounded. Farther back the caudal margins of the keels become first straight and transverse, and then bend back, thus making the posterior corners acute. Keels of the eighteenth and nineteenth segments bent back conspicuously, with the posterior corner presenting a short dentiform or spinous point.

Last tergite much wider than long.

First legs of male not crassate, without special processes.

Gonopods with solenomerite free, prolonged distally into a slender style; one broad lobe on the preaxial side as shown in figs. 1 and 2.

Width, 12–13 mm.

Localities.—BRITISH HONDURAS: Bukowina, male ***holotype*** and four females taken Oct. 27, 1939, by Ivan T. Sanderson; Double Falls, three females taken Dec. 17, 1939, also by Sanderson.

Sphaeroidesmus cobanus, new species

Figs. 3, 4

Color not evident in the type.

Collum not fusiform; caudal margin convex, with lateral margins forming a subsemicircular outline; anterior margin nearly straight, the anterior corners more narrowly rounded.

Keels of fourth segment sigmoidal, the concave posterior margin curving back to the corner; anterior margin presenting the usual elevated rim, that of the two preceding keels similarly raised. Fifth tergite of same width as the fourth, its keels a little bent back, the lateral ends evenly rounded. Posterior corners of keels of segments toward posterior end of body becoming more acute as usual. Last tergite wider than long.

Femur of first leg of male with a conical angle or setiferous tubercle at base on anterior side, the joint moderately curved, the anterior margin being a little incurved.

Gonopods of male with three distal branches, with one of which the solenomerite is united excepting at its tip as shown in figs. 3 and 4.

Width, 6 mm.

Locality.—GUATEMALA: Coban, male ***holotype*** taken by K. P. Schmidt, Mar. 25, 1934; Alta Vera Paz, a male and female taken Mar. 20, 1934, also by Dr. Schmidt.

Sphaeriodesmus coriaceus Pocock

Sphaeriodesmus coriaceus Pocock, 1910, Biol. Centrali-Amer., Chilipoda and Diplopoda, p. 125, pl. 9, figs. 4–4b.

Locality.—GUATEMALA: Volcan Tajumulco, two specimens taken Feb. 21, 1934, by K. P. Schmidt.

This species was described originally from San Juan in Alta Vera Cruz.

Family **Cryptodesmidae**

Genus **Caliodesmus**, new

Body composed of twenty segments.

Antennae short, clavate.

Collum fan-shaped, large, completely covering the head from above; anterior margin an evenly convex curve; the anterolateral border divided into 24 areas by radial lines but the margin not correspondingly notched, wholly smooth.

Intercarinal dorsum of each segment with 4 to 6 transverse series of small, well separated, setigerous tubercles. Keels wide, moderately narrowed from the base distad; anterior corners rounded, the posterior

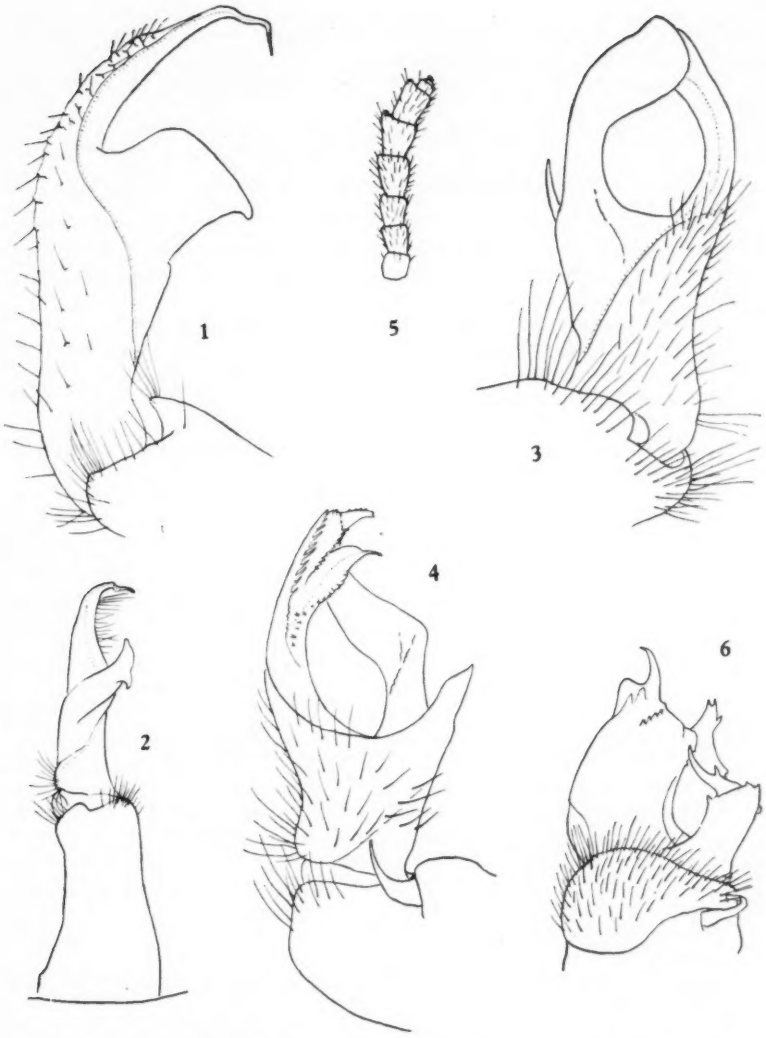


FIG. 1. *Sphaeriodesmus bukowinus*, n. sp. Left gonopod, ectal aspect. FIG. 2. The same. Right gonopod, cephalic aspect, drawn on smaller scale. FIG. 3. *Sphaeriodesmus colanus*, n. sp. Right gonopod, ectal aspect. FIG. 4. The same. Right gonopod, mesal aspect. FIG. 5. *Caliodesmus phanus*, n. sp. Antenna. FIG. 6. The same. Left gonopod, mesal aspect.

acute and on posterior segments prolonged; lateral margins with setigerous teeth, the posterior margins also with seta-bearing teeth or crenatures, the anterior margin smooth. Pores normal in distribution, each opening above toward base of keel.

Gonopodal opening large, transversely broadly elliptic, with the rim prominently raised.

Generotype.—*Caliodesmus phanus* n. sp.

Caliodesmus phanus, new species

Figs. 5–9

Middorsal region brown, the keels similarly colored excepting their anterior border and a large elliptical submedian area which are orange or yellow. Legs yellow and antennae brown.

Antennae short and moderately clavate as shown in fig. 5.

Collum broadly fan-shaped with base truncate, much wider than the head which it completely conceals from above; anterior margin widely convex, the posterior margin nearly straight at middle, each lateral portion gently concave and meeting the anterolateral margin in an acute angle; anterior border divided by radiating lines into 24 areas, the margin not correspondingly notched.

Keels in general proportionately short in the anteroposterior direction but transversely long, narrowing gently from base outward; caudal corner acute, with lateral margin running obliquely mesad or cephalad to the rounded anterior corner; lateral margin with 5 teeth and the caudal margin with 9 teeth or scallops, each tooth bearing a straight seta. In the posterior region the keels bend caudad and the posterior corners are prolonged, the keels of the 19th segment running directly caudad with their apices on a level with that of the cauda.

Dorsum between keels with small but well developed tubercles arranged typically in six transverse series which tend to be irregular; the tubercles across the caudal border laterally compressed and appearing as short longitudinal ridges.

Last tergite long, much exceeding the valves, narrowed from base to the broadly rounded caudal end, with four setigerous teeth on each side (*cf.* fig. 9). Anal scale proportionately broad, trapeziform, a prominent setigerous tubercle at each posterior corner. Inner border of anal valves raised and set off by a groove.

Gonopods as represented in fig. 6.

Length, 19 mm.; width, 5 mm.

Locality.—COLOMBIA: Cali. The male *holotype* was taken July 30, 1937, by H. Dybas.

Family **Polydesmidae**

Dixidesmus conlatus (Chamberlin)

Polydesmus conlatus Chamberlin, 1943, Proc. Biol. Soc. Washington, 56: 36, fig. 5.
Dixidesmus conlatus Chamberlin, 1943, Bull. Univ. Utah, Biol. ser., 8(2): 18.

Locality.—TENNESSEE: Smoky Mt. National Park, Greenbriar Cove. Males and females taken by H. Dybas Jan. 14–19, 1942.

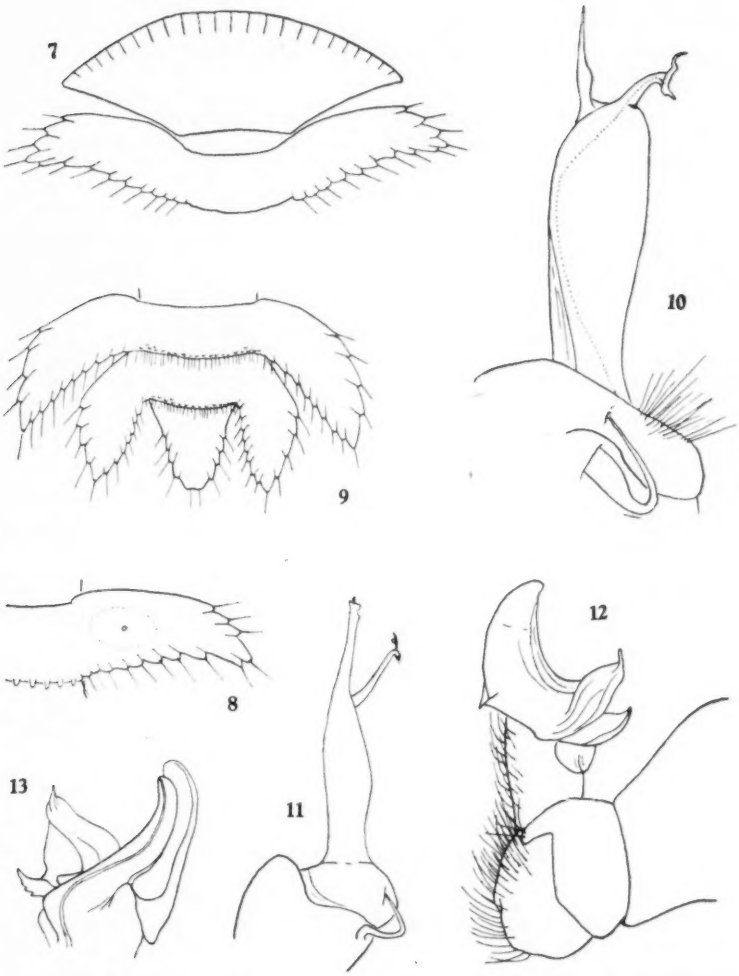


FIG. 7. *Caliodesmus phanus*, n. sp. Collum and second tergite in outline. FIG. 8. The same. Right keel of segment V. FIG. 9. The same. Tergites 18, 19, and 20. FIG. 10. *Pinesmus monticolens*, n. sp. Gonopod, ventromesal FIG. 12. *Trichomorpha man-ananus*, n. sp. Left gonopod, ectal aspect. FIG. 13. The same. Apical part of left gonopod, cephalomesal aspect.

Polydesmus coriaceus Porat

Polydesmus coriaceus Porat, 1870, Ofvers. Vetensk. Akad. Förh., no. 7, p. 189, fig. 7.

Locality.—ILLINOIS: Chicago. Specimens collected by H. Dybas, Mar. 20, 1942.

Pseudopolydesmus hubrichti (Chamberlin)

Polydesmus hubrichti Chamberlin, 1943, Ent. News, 54: 15, figs. 1, 2.
Pseudopolydesmus hubrichti Chamberlin, 1943, Bull. Univ. Utah, Biol. Ser., 8(2): 18.

Localities.—ARKANSAS: Garland Co., 11 mi. W. of Hot Springs, one male taken by K. P. Schmidt Mar. 21, 1938; Imboden, Lawrence Co., a male also taken by K. P. Schmidt April 3, 1937. MISSOURI: St. Francis Co., Libertyville, a male taken April 2, 1937, by Dr. Schmidt.

Pseudopolydesmus modocus (Chamberlin)

Polydesmus modocus Chamberlin, 1943, Proc. Biol. Soc. Washington, 56: 36, fig. 6.
Pseudopolydesmus modocus Chamberlin, 1943, Bull. Univ. Utah, Biol. Ser., 8(2): 18.

Locality.—ILLINOIS: Randolph Co., between Modoc and Roots, April, 1936, one male taken by K. P. Schmidt.

Scytonotus granulatus (Say)

Polydesmus granulatus Say, 1821, Jour. Acad. Nat. Sci. Philadelphia, 2: 107.
Scytonotus granulatus Bollman, 1893, Bull. U. S. Nat. Mus., no. 46, p. 000.

Localities.—ILLINOIS: Monee, several taken Mar. 24, 1908, by H. Ramstadt. INDIANA, exact locality not given, four specimens taken April 18, 1942.

Tidesmus episcopus Chamberlin

Tidesmus episcopus Chamberlin, 1943, Proc. Biol. Soc. Washington, 56: 35, figs. 1–3.

Locality.—CALIFORNIA: Los Angeles, Bishop's Road, Reservoir Hill. Four specimens taken Jan. 2, 1933, by G. Grant.

Family **Periodontodesmidae**

Pinesmus monticolens, new species

Fig. 10

Metatergites and under side of keels reddish or chestnut, the prozonites, lower part of sides, and venter of metazonites yellow. Legs and antennae yellow.

Collum with lateral ends moderately widely rounded; the anterior margin convex, the caudal arcuate; surface densely covered with conical setigerous tubercles which form about seven somewhat irregular transverse series.

The keels of segments 2 to 4 bent forwards, with anterior corners produced and acute, the caudal corners well rounded off.

On subsequent keels the anterior margin becomes transverse, with the anterior corner subrectangular, the posterior corner rounded on segments back to middle of body and thereafter first subrectangular

and then broadly a little produced on segments 18 to 19 but not acute. Surface of tergites with five transverse series of conical setigerous tubercles on all segments, the number of series not increased on the more posterior segments as in the case in *viganus*.

Gonopods as represented in fig. 10.

Length, about 9 mm.

Locality.—GUATEMALA: Volcan Tajumulco. *Holotype* male taken Feb. 13, 1934, by K. P. Schmidt (Mandel Expedition).

Pinesmus viganus, new species

Fig. 11

Dorsum uniform brown. Legs and antennae yellow.

Collum transversely subfusiform; dorsal surface densely covered with conical setiferous tubercles.

Second tergite with keels bent moderately forward; lateral margin only slightly convex, presenting six subequal teeth; caudal margin typically with five teeth which decrease in size mesad. Keels 3 and 4 shorter enterocaudally than the second, with caudolateral corners rounded off, the teeth of lateral and caudal margins forming an even series, the anterior corner projecting farther laterad with the lateral margin thus oblique. On segments farther back the lateral margin of keels becomes parallel with axis of body and bears mostly six teeth, and the caudal corner becomes less rounded, becoming first rectangular and then on segments 17 to 19 moderately acutely produced with keels as a whole bending a little caudad. The keels of the 19th segment reduced in size. Metatergites mostly with five transverse series of setigerous tubercles, but on the more posterior segments the tubercles are more numerous and in more series although these are less clearly defined. Anal tergite also densely covered with conical setigerous tubercles.

Gonopods as shown in fig. 11.

Length, 7.5–8 mm.

Locality.—MEXICO: Vera Cruz, Las Vigas at 5,500 ft. *Holotype* male and three additional specimens taken by H. Dybas.

Family **Rachodesmidae**

Genus **Euphallus,** new

Segments and pores normal in number. Anterior border of keels not produced; caudal corners not produced excepting moderately on last few segments. Surface of tergites smooth, without transverse sulcus. Keels well separated.

In most structural characters close to *Metaphallus* but differing in the gonopods. In these the coxa is very short and the prefemur relatively very long. Mesal face of telopodite excavated. At distal end of telopodite three processes of which the ectal is setiferous and is probably an extension of the prefemur; the mesal one is a lamina continuous with the reflexed mesal border of the telopodite and seems to be femoral in derivation. The middle process is a larger lamina representing the tibiotarsus and to its concave caudal face is closely

applied to the slender solenomerite which is distally free and typically shortly furcate. The seminal channel is distinct to the proximal end of the mesal excavation.

The genital opening on the coxa of the second legs of the male is sessile, with behind it a short slender process and in front of it two small setiferous tubercles.

Generotype.—*Euphallus dybasi* n. sp.

Differing from *Metaphallus* in lacking the mesal process or one lamina at the distal end of the telopodite of the gonopods, in the reduced coxa and the much longer prefemoral division.

Euphallus dybasi, new species

Figs. 19–22

The dorsum of the type specimens, which may not be in full color, is yellow showing an olicaceous tinge. Legs and antennae yellow.

Vertigial sulcus deep, furcate in front at level of antennae. Short setae on clypeal and frontal areas up to level of antennae.

The collum wider than the head; anterior margin convex, the anterior corners rounded and the lateral margins convex; caudal margin incurved at middle and bending forward on each side to the posterior corner of the keel which is more narrowly rounded than the anterior corner.

Width of tergites across keels decreasing from second to the fifth. The form of these keels is shown in fig. 21. Keels set high, with the intervening dorsum only weakly convex. Dorsal surface nearly smooth or a little rugose on the keels, but the sides between keels and legs somewhat granular. Proliferous calli well developed but not reaching the caudal corner of keel excepting on the last three segments, the result being a distinct indentation between callus and middle posterior margin of tergites which is especially conspicuous on segments 12, 13 and 15. (See further fig. 9.)

Anal scale distinctly triangular.

In the male two rounded setiferous tubercles in front of the genital opening on coxa of second legs and a small acuminate process, swollen at base, behind it.

Sternites with a rather deep longitudinal sulcus; setose; in the male with no special processes.

The gonopods as represented in figs. 19, 20.

Width of male, 3.6 mm.

Locality.—MEXICO: Vera Cruz, El Fortin. The male *holotype* and an immature specimen taken July 10, 1941, at an elevation of 3,000 ft. by H. Dybas.

A female in the same vial is much larger, having a width of 4.2 mm. but is probably the same species.

Genus **Metaphallus,** new

Body composed of twenty segments. Pores normal in arrangement and number.

Keels set high, horizontal, large; anterior margin convexly bulging; keels longer anteroposteriorly than median part of metatergite; caudal

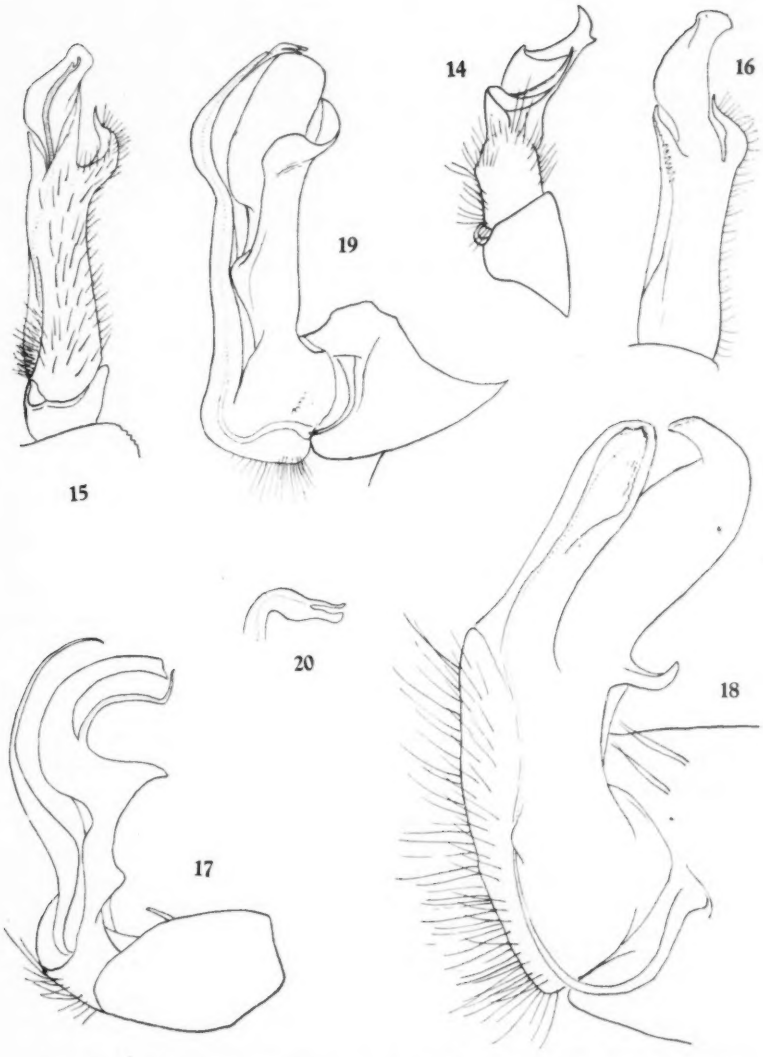


FIG. 14. *Chondrodesmus araguanus*, n. sp. Left gonopod, caudal aspect. FIG. 15. *Iguazus leius*, n. sp. Left gonopod, ectal aspect. FIG. 16. *Leptodesmus piraputangus*, n. sp. Left gonopod, mesal aspect. FIG. 17. *Leptodesmus therezopolis*, n. sp. Right gonopod, mesal aspect. FIG. 18. The same. Distal end of solenomerite. FIG. 19. *Euphallus dybasi*, n. sp. Left gonopod, postaxial view. FIG. 20. The same. Right gonopod, preaxial view.

corners on anterior segments not produced, but toward caudal end becoming gradually produced. Surface of tergites typically in part with minute granules.

Differing from *Aceratophallus* and *Tiphallus* in the structure of the gonopods. These are similar to those of *Aceratophallus* in presenting a slender tibiotarsal process at the end of the telopodite on the ectal side and a slender solenomerite on the mesal side, but there is in addition a third process in the form of a narrow lamina paralleling and lying against the solenomerite.

Generotype.—*Metaphallus mimus* n. sp.

Metaphallus mimus, new species

Figs. 23–26

Color in type faded, testaceous.

Antenna more slender than in *e.g., Tiphallus aberrans.*

Collum with anterior margin more convex at middle than laterally, not forming an even curve with lateral margins (*cf.* fig. 23).

In the following segments the anterior as well as the posterior corners subrectangular, all with a denticle on outside of anterior corner (*cf.* fig. 24). Farther caudad the anterior margin of keels becomes more convex and more oblique. Back of the middle of the body the posterior corners become a little produced and extend into distinct triangular processes on segments 17 to 19, the processes of the 19th reduced and apically narrowly rounded. Lateral margins of keels moderately convex and smooth except the denticle at the anterior corner and this becoming obscure or obliterated on the more posterior segments. Poriferous calli moderately developed but not constricted off.

Cauda moderately exceeding the anal valves.

Gonopods represented in figs. 25 and 26.

Length, near 29 mm.; width, 4 mm.

Locality.—GUATEMALA: Chichivac. Male *holotype* and several additional specimens taken Feb. 4–7, 1934, by K. P. Schmidt (Mandel Expedition).

Genus **Phorositus,** new

Number of segments and number and distribution of pores normal.

Keels set high on segments with the intervening dorsum but moderately arched. Keels well developed but smaller than in *Aceratophallus*, not overlapping. Dorsal surface granular and typically with a single series of small tubercles along caudal border.

Legs and sternites unmodified in the male.

Gonopods with the telopodite distally with two branches as in *Aceratophallus*, but the solenomerite distally ending in a slender style rather than being button-like, and the outer branch a simple, acuminate process. Inner face of prefemur widely and conspicuously excavated.

Generotype.—*Phorositus granulifer* n. sp.

Phorositus granulifer, new species

Fig. 27

The types apparently not in full color, the dorsum at present a dull or greyish testaceous yellow, with the keels brighter. Legs and antennae yellow.

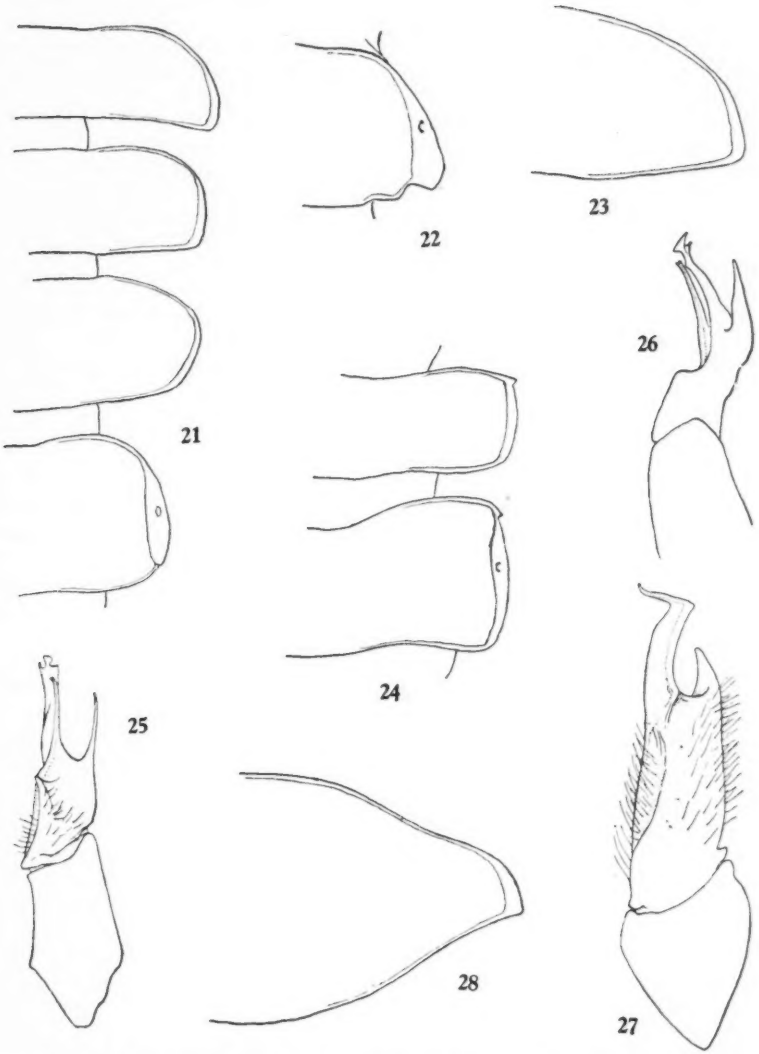


FIG. 21. *Euphallus dybasi*, n. sp. Right keels of segments 2 to 5. FIG. 22. The same. Right keel of segment 15. FIG. 23. *Metaphallus mimus*, n. sp. Right end of collum. FIG. 24. The same. Right keels IV and V. FIG. 25. The same. Gonopod, caudal aspect. FIG. 26. The same. Gonopod, caudoextal aspect. FIG. 27. *Phorbsitus granulifer*, n. sp. Left gonopod, postaxial aspect. FIG. 28. *Aphelidesmus major*, n. sp. Right end of collum in outline.

Head clothed with numerous short, erect hairs over vertex as well as lower parts. Sulcus sharply impressed.

Collum with caudal margin strongly arcuate, the posterior corners produced caudoectad; anterior corners widely rounded and the median part of anterior margin straight.

On the following segments the keels are set high with the intervening dorsum but little convex. The posterior corners of the keels are widely produced in increasing degree toward caudal end, but the processes of the nineteenth reduced; a minute tooth on lateral side of anterior corner detectable on most keels. A shallow transverse furrow across metatergites but this not at all sulciform. Dorsal surface of metatergites densely and evenly granular, the granules elevated, not at all flattened, well separated at base; the pleural region below keels similarly granular. The caudal series of tubercles on metatergites usually four to six in number, the tubercles small and low. The poriferous keels not swollen at border, the pores opening laterad on the edge.

Cauda narrowed to a blunt point. Anal scale triangularly produced between its two caudal setae.

Gonopods as drawn (fig. 27).

Width of male, 2.5 mm.; of female, 3 mm.

Locality.—GUATEMALA: Volcan Tajumulco. Three males, including *holotype*, and six females taken Feb. 24, 1934, by K. P. Schmidt (Mandel Expedition).

Rachidomorpha aurantium, new species

Figs. 30, 31

General color of body orange, the legs mostly yellow.

Antennae long and filiform, the second, fourth and fifth articles longest, subequal in length and width.

Collum with caudal margin arcuate, curving back laterally to apex of the caudal angle on each side; anterior and lateral margins together evenly convex; surface smooth and shining.

On the following tergites the caudolateral angles are produced and elevated in increasing degree from the second to the fifth segment from where the processes continue of nearly uniform and conspicuous length and to be elevated at an angle of about 45 degrees, with the lateral margin curving evenly from the acute apex of the process to the anterior base of keel, smooth except for an anterior tooth. Surface of tergites smooth, with a shallow but distinct transverse furrow which curves back at its ends. Processes of 19th keels relatively reduced. Anal tergite narrowly rounded at apex. Anal scale subtriangular, the caudal angle produced between the setae.

Sternites smooth.

General features of the gonopods shown in figs. 30 and 31. The hairs of the conspicuous brush arising on the postaxial face of the prefemur are very long and curve about base of the outer lobe to the base of the short solenomerite.

Width, 3 to 3.25 mm.

Locality.—MEXICO: Vera Cruz, El Fortin. Twelve specimens, including holotype male, taken at an elevation of 3,000 ft. on July 9, 1941, by H. Dybas.

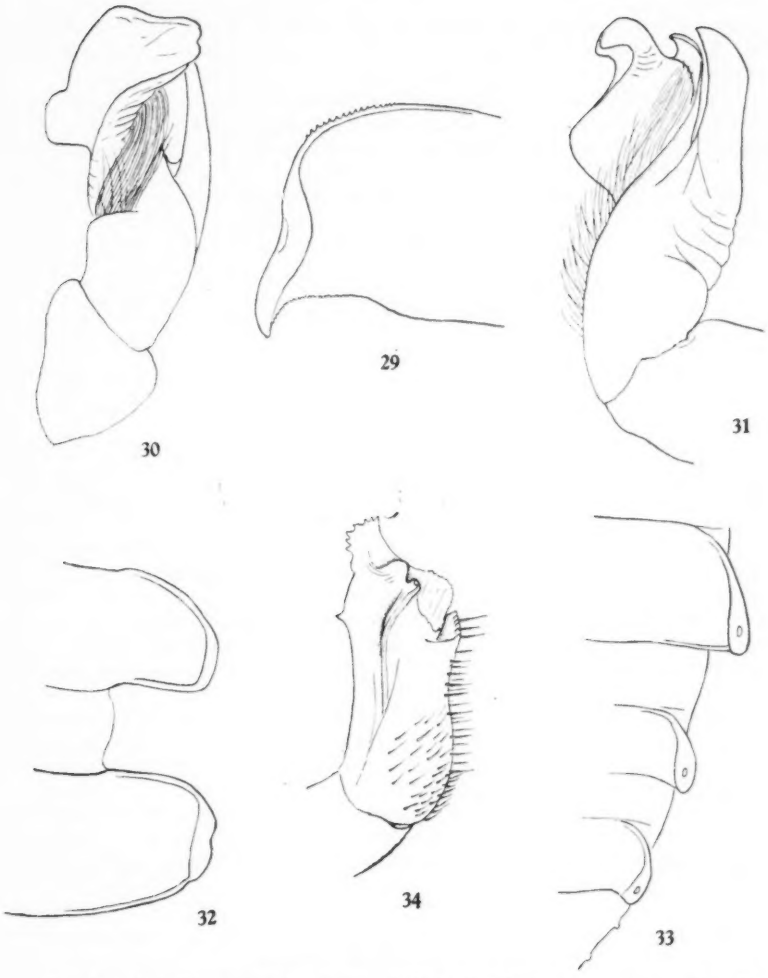


FIG. 29. *Aphelidesmus major*, n. sp. Left keel of fifteenth segment. FIG. 30. *Rachidomorpha aurantium*, n. sp. Right gonopod, posterior aspect. FIG. 31. The same. Right gonopod, submesal aspect. FIG. 32. *Tiphallus aberrans*, n. sp. Right keels of segments IV and V. FIG. 33. The same. Right keels of segments XVII to XIX. FIG. 34. The same. Gonopod, mesal aspect.

Genus **Tiphallus,** new

Segments and repugnatorial pores normal in number.

Keels smaller and shorter than in *Aceratophallus* and not overlapping, the posterior corners of the anterior keels not produced. Surface of tergites smooth or nearly so and without a transverse sulcus.

In the gonopods in place of the more or less elongate, distally setose ectal process of the tibiotarsus in *Aceratophallus*, there is a thin lamina rising from and extending about the outer and anterior part of the circumference of the distal end; and in place of the styliform solenomerite the latter is reduced to a short, rounded cone between which and the outer lamina there is a low conical process.

Generotype.—*Tiphallus aberrans* n. sp.

Tiphallus aberrans, new species

Figs. 32–34

Color faded after preservation, at present showing the testaceous color usual under the conditions, but the keels evidently lighter, yellowish. Legs and antennae also yellowish.

In the antennae the articles 2, 3, 4, and 5 nearly equal in length, but the sixth distinctly longer than these. Vertigial sulcus ending above level of antennal sockets. The head was apparently darker over vertex than below.

In the collum the anterior and lateral margins together form an evenly convex curve, while the caudal margin is straight and transverse at the sides and incurved at the middle.

In the following keels both the anterior and the posterior corners are convexly rounded; the anterior corners gradually becoming more rounded off or oblique. The lateral margins of the keels are smooth and convex. The pores open through pronounced calli. The posterior margin of the keels become straight and transverse on the 17th segment, run a little caudad of ectad on the 18th, and on the 19th the posterior corner extends into a short, distally rounded process. (fig. 33). Dorsal surface of tergites wholly smooth.

Cauda prominently exceeding the anal valves, moderately decurved. Caudal angle of anal scale acute.

Locality.—MEXICO: San Luis Potosi, Tamozunchale. Several taken June 19, 1941, by H. Dybas.

Family **Eurydesmidae**

Chondrodesmus sabachanus Chamberlin

Chondrodesmus sabachanus Chamberlin, 1938, Carnegie Inst. Washington, Publ. no. 491, p. 174, figs. 29–32.

Locality.—YUCATAN: Mugeres Id. One female taken Jan. 26, 1940, by D. D. Davis.

Original types were from a cave at Tekax, Yucatan.

Chondrodesmus araguanus, new species

Fig. 14

Entire body black excepting the outer part of keels and the cauda which are bright yellow. Head also black. Legs and antennae yellow.

Caudal margin of collum arcuate, the anterior margin convex and continuing evenly about the rounded anterior corners and back to the caudal corners which are rectangular or but slightly acute. Tubercles on collum few and widely separated, in three irregular rows. Borders sharply margined.

On the following tergites the keels have the anterior margin convex and the anterior corner rounded, while the posterior margin is first straight and farther back concave, with a distinct tooth which becomes larger and more acute on the posterior segments; the posterior corners, in proceeding back, become more and more acute and produced. The keels and processes on the 19th segment much reduced. Surface of metatergites irregularly rugose, more finely so on the keels, with the tubercles few and inconspicuous; the surface in general also granular. The pores open dorsad on the marginal thickening.

Gonopods as drawn (fig. 14).

Length, about 54 mm.; width, 8 mm.

Locality.—VENEZUELA: near Maracay, Aragua, at "Hacienda la Trinidad." Two males, *holotype* and *paratype*, taken by Padre Cornelio Vogl in 1940.

Genus **Iguazus,** new

Body composed of twenty segments.

Repugnatorial pores normal in distribution.

Tergites highly arched, smooth and without transverse sulcus. Keels narrow, more reduced on the last segments; excepting an anterior segments widely separated.

Sternites and legs without special processes in the male. Legs lacking pads.

Anal scutum triangularly narrowed caudad.

Gonopods with coxae united at the median plane, these with the usual hook and in addition a spinous process on the anterior side. Prefemoral division short, with a curved blade or lamina as in *Leptodesmus*. Acropodite distally presenting two well separated branches of which the mesal one is the solenomerite, this being a long, slender curved style.

Generotype.—*Iguazus leius* n. sp.

Iguazus leius, new species

Fig. 15

Metatergites brownish grey, the prozonites and under parts lighter grey, the metatergites darker along caudal border. Legs and antennae light brown.

Vertex of head smooth and shining; median sulcus extending forward to level of antennae sockets. Clypeal foveolae 2–2, the two inner ones widely separated and each outer one submarginal in position.

Collum semicircular; margined anteriorly and along sides back to the caudal corners; surface otherwise smooth and shining.

Keels of the following three segments contiguous, their lateral margins moderately convex with border elevated. Following these the keels become widely separated. Keels bent downward, continuing smoothly the curvature of the elevated dorsum. Beginning with the fifth segment the posterior corners of the keels are a little produced but the processes in no case long. Keels of the 19th segment greatly reduced, appearing only as a slight elevation surrounding the pore. Dorsal surface of all tergites appearing smooth and shining, but under magnification showing as somewhat corairious. Prozonites without encircling striae.

Caudal process much exceeding the valves. Anal scale broadly subtriangular, caudally with two prominent tubercles placed rather close together. Anal valves with inner border conspicuously elevated; two prominent setigerous tubercles adjacent to the elevated border on each side.

Gonopods as drawn (fig. 15).

Width, about 7 mm.

Locality.—ARGENTINA: Iguazu Falls, Missiones. Two males, including *holotype*, and six females. (Marshall Field Expedition.)

Leptodesmus carneus (Saussure)

Polydesmus carneus Saussure, 1859, Linn. Ent., 18: 324.
Polydesmus (*Leptodesmus*) *carneus* Saussure, 1860, Myr. de Mexique, p. 46, fig. 15.

Locality.—BRAZIL: State of Rio, Therezopolis. Two males taken July 4, 1926, and one female taken July 9, 1926. (Marshall Field Expedition.)

Leptodesmus therezopolis, new species

Figs 17, 18

Color above and laterally from light yellowish brown to dark brown of chestnut cast, the prozonites more reddish than the metazonites, the keels not differently colored. Legs and antennae from yellow to light chestnut.

Head and vertigial sulcus fine but distinct. Frontal and clypeal area with numerous setae.

Collum much wider than the head, at sides somewhat symmetrically narrowed to a subacute, narrowly rounded angle, the anterior margin convex, the posterior nearly straight; surface smooth and shining.

Segments deeply constricted at the segmental furrow. Prozonites essentially smooth, the metatergites finely, and in front only obscurely, shagreened. Dorsum only moderately arched. The keels inserted high and continuing the curvature of the dorsum. Keels 2 to 4 with lateral margins smooth, moderately convex, the anterior and posterior corners equally a little obtuse. From the fifth segment on the anterior corners of the keels are well rounded off, the posterior corners first rectangular and then a little acute but never more than slightly produced beyond line of middle posterior margin of the tergite.

Anal tergite extending well beyond the valves, strongly narrowed

and subcylindrical distally, the tip rounded. Anal scale triangularly produced at middle as usual between the two caudal setae.

Sternite between fourth pair of legs of male bearing a process which is distally bifid, the two lobes rounded. Sternite of sixth segment with a slight setiferous swelling at base of each anterior leg.

Pleural keels on anterior segments of male presenting a sharp, finely crenate edge, this keel becoming obscure and finally obliterated in going caudad.

The gonopods of the male place this species in the small group in which the solenomerite is separated well down to the prefemoral section of the telopodite and in the group having the solenomerite conspicuously curved, the only other known Brazilian species having this character being *L. pulvillatus* Attems of the Amazon region. The solenomerites distally furcate. For other details see figs. 17 and 18.

Width, 4.5 mm.

Locality.—BRAZIL: 5 mi. N. of Therezopolis, Rio. Four males, including holotype, and one female taken at an elevation of 3,500 ft. on July 5, 1926. (Marshall Field Expedition.)

Leptodesmus piraputangus, new species

Fig. 16

Dorsum and sides reddish to dark chestnut, with caudolateral corners of keels, tip of cauda and usually a narrow caudal band across tergite yellow, the caudal border of tergite down the sides also commonly edged with yellow, the yellow dorsal band often widened at middle into a deltoid area. Legs light chestnut, the apices of articles and especially the proximal articles more or less yellowish. Antennae light chestnut, but the seventh article typically yellow. Head darker in front than on the vertex.

Setae in clypeal area few, short. Vertex glabrous, its sulcus sharply impressed.

Collum much wider than the head; subfusiform in outline, nearly symmetrically narrowed to the narrowly rounded lateral angle; anterior margin straight at middle, the posterior gently incurved at middle.

The keels of the subsequent segments in general as described for *therezopolis*. Surface of anterior tergites nearly smooth but that of the last several, including the broad basal area of the last segment, densely finely granular.

Anal tergite and valves of typical form. The anal scale transversely depressed across basal portion; a ridge connecting the caudal setiferous tubercles, the triangular apical portion of plate depressed.

In the male there is a pair of small rounded prominences on the sternite between the fifth pair of legs, a pair of longer ones, fused at base, between the sixth legs; other sternites not modified. Pleural keels well developed on anterior segments.

In character of gonopods falling in the group with *cerasinus*, *biconicus*, etc., in which the solenomerite is fused, except at very tip with the main branch of the acropodite. It seems to be distinguishable from other species of the group in the form of the inner, prefemoral, process as represented in fig. 16.

Width, 5 mm.

Locality.—BRAZIL: Matto Grosso, Piraputango. Five specimens, including holotype male, taken July 26, 1926. (Marshall Field Expedition.)

Quisquicia insignis (Chamberlin)

Caraibodesmus insignis Chamberlin, 1918, Bull. Mus. Comp. Zool., 62: 234.

Locality.—HAITI: Kershoff. Two specimens taken at 4,500 ft. on Dec. 2, 1928, by K. P. Schmidt. This is the type locality for the species.

Trichomorpha manzanaris, new species

Figs. 12, 13

Dorsum and sides dark brown to chestnut, with lateral border and caudolateral corner of keels, venter, legs and antennae light brown.

Collum with anterior and lateral margins together forming an evenly convex, semicircular curve between the caudolateral angles; caudal margin strongly arcuate; the caudolateral corners produced caudad.

On the following segments the dorsum is but slightly convex; keels inserted high, thick or swollen through the base, with lateral border relatively thin and upturned. Caudal angles of keels strongly produced, more and more so toward caudal end. Lateral margin smooth, a single distinct denticle toward anterior corner; also a tooth on caudal margin of keel. Transverse sulcus on metatergites deep; middle portion smooth or but little irregular, but granular toward base of keels. Segments deeply constricted, with prozonites smooth throughout.

Sternites with no distinct processes in the male. Metatarsal pads projecting distad beneath the tarsi are present in the male back to the legs of the 16th segment.

Rim of gonopodal cavity very high at the sides, excavated anteriorly. Gonopods as drawn (figs. 12, 13).

Width of female, 2.8 mm., the male a little narrower.

Locality.—COLOMBIA: Rio Rondo in the region of Santa Marta and Manzanaris. Five specimens, including male holotype, taken July 25–Aug. 1, 1902, by H. H. Howland.

Trichomorpha rondonum, new species

A conspicuously marked form in which the keels and a band over border of tergites are white, with the caudal band extending forward at middle nearly to the anterior margin, the remaining part of metatergites and prozonites brown. Sides brown, in part of a somewhat bluish tinge. Venter greyish yellow or in parts nearly white. Legs and antennae yellow.

Collum with anterior margin convex, rounding about anterior corners. Caudal corners subrectangular.

On the following segments the caudal corners acutely produced as usual; lateral margin on first keels showing a weak serration in the form of three undulations or slight teeth in the angle of each of which there is a seta. Farther back most two weak or obscure denticles are detectable, the anterior of these better developed, obtuse. Dorsal

surface of metatergites strongly granular on and adjacent to bases of keels; some low tubercles on area back of the transverse sulcus.

Width, 2.5 mm.

Locality.—COLOMBIA: Rondo River in vicinity of Santa Marta and Manzanaris. Female holotype taken July 25–Aug. 1, 1902, by H. H. Howland.

While this species is based upon the female only, the conspicuous color pattern and sculpturing of the tergites should serve to distinguish it.

Harpaphe haydeniana (Wood)

Polydesmus haydeniana Wood, 1864, Proc. Acad. Nat. Sci. Philadelphia, 1864: 10.
Polydesmus (*Leptodesmus*) *haydeniana* Wood. Trans. Amer. Phil. Soc., (2), 13: 226, fig. 57.
Harpaphe haydeniana Cook, 1904, Harriman Alaska Exped., vol. 8, p. 59, with unnumbered figs.

Locality.—WASHINGTON: Olympus Mts., Happy Lake. One male.

Iphyria rubripes, new species

Dorsum chocolate colored excepting the caudolateral part of the keels which is yellow. Legs and antennae reddish, probably partly faded in the alcohol. No trace of a median dorsal light stripe such as is present in *claralata*.

Collum with anterior and lateral margins together forming an evenly convex curve; the posterior margin arcuate with the middle portion strongly incurved.

Subsequent keels nearly as in *claralata*, the posterior corners being similarly produced distinctly only on segments 16 to 19, with the processes of the 19th keels reduced in size, the processes increasing in the width across base from segment 19 to 16. Keels with raised margins. Dorsal surface of all tergites smooth.

Cauda conspicuously narrowed caudad as usual, the tip truncate; with four pairs of dorsal or subdorsal setae; irregularly transversely wrinkled. Anal scale triangular, the caudal angle acute; transversely depressed across base. Inner border of each anal valve sharply elevated and set off, the rim bearing a long seta toward upper end, with a second seta in the usual position farther ventrad and ectad of the rim.

Spine at distal end of prefemur of legs rather large.

Width, 6.8 mm.

Locality.—PERU: Hacienda Limon, 10 mi. W. of Bulgas. Holotype female taken by Asybod and Anderson May 8, 1912.

This is a much smaller form than *claralata*, from which it differs superficially also in color in not having a median dorsal pale stripe and in the red color of the legs.

Rhysodesmus amplinus, new species

Dorsum light brown, with keels yellow, but with no transverse light bands. Legs and antennae yellow.

Median sulcus across vertex to level of antennae. Head with sparse short setae, otherwise smooth and shining.

Collum much wider than head, wider across posterior border than the anterior; anterior margin nearly straight; the anterior corners widely rounded, the posterior narrowly rounded; posterior margin arcuate; surface smooth and shining.

On the keels of the following segments the anterior margin convex, rounding about the anterior corners; the posterior margin more and more concave, leaving the posterior corners angular and moderately produced; keels longer anteroposteriorly than the middle part of metatergite. On the first few tergites the sculpturing is weak, but on those of middle and posterior segments strongly marked in the form of three transverse series of elevated areas or large, close-set tubercles of which those in middle of anterior series are more or less vague or obliterated; tubercles vague on the keels where they are in part replaced by low, irregular longitudinal rugae. Keels margined anteriorly and laterally, the lateral elevated border thick, especially on the poriferous keels.

Sternites not excised.

Caudal tergite conspicuously narrowed caudad, truncate at end, the distal portion a little curved downward; with some transverse wrinkles or sulci across basal portion. Anal scale roughly triangular, the basal angles rounded, the median produced beyond level of the two caudal setae which are sessile.

Gonopods of usual general form.

Length, 40 mm.; width, 8 mm.

Locality.—MEXICO: El Fortin in Vera Cruz. Several males, including holotype, and females taken July 4–7, 1941, by H. Dybas.

A somewhat smaller form than *R. cumbres* Chamb., a species also occurring in Vera Cruz, and differing in its lighter color and especially in the *Amplinus*-like sculpturing of the tergites.

Rhysodesmus marcosus, new species

Dorsum brown, the entire keels light brown or yellowish. Legs and antennae pale brown to yellowish.

Median sulcus across vertex of head sharply impressed to level of antennae; vertex glabrous and smooth.

Collum much wider than the head; anterior and lateral margins together forming a convex curve somewhat flattened at middle; caudal margin widely incurved at middle; surface smooth and shining.

Dorsum strongly convex. Keels bent downward and nearly evenly continuing the curvature of the intervening dorsum; undergoing the usual change in outline in proceeding from the anterior to the posterior segments, the posterior corners becoming more and more produced; the keels of the 19th segment shorter but broad and rounded.

Anal scale obtusely angular between the two setiferous tubercles.

Gonopods of typical form.

Length of male, 42 mm.; width, 10.5 mm. Length of female, 52 mm.; width, 11.5 mm.

Locality.—GUATEMALA: El Provenir, San Marcos. Male holotype and female allotype taken March 2, 1934, at 3,400 ft. by K. P. Schmidt. (Mandel Expedition.)

Rhysodesmus pater Chamberlin

Rhysodesmus pater Chamberlin, 1943, Bull. Univ. Utah, Biol. Ser., 8(3): 45, figs. 97, 98.

Locality.—MEXICO: Vera Cruz, El Fortin. One male taken July 7, 1941, by H. Dybas.

This specimen, which is from the type locality, is in full color. The broad keels are entirely bright yellow, this color on the collum extending also in a band across anterior border; prozonites dull yellow; metatergites between keels brown. Legs and antennae yellow. In size and proportions this male agrees precisely with the original type, the length being 45 mm. and the width 11 mm.

Rhysodesmus potosianus Chamberlin

Rhysodesmus potosianus Chamberlin, 1942, Canadian Ent., p. 91, fig. 2.

Locality.—MEXICO: San Luis Potosi. One male (type of the species) taken July 12, 1941, by H. Dybas.

Family **Eurymerodesmidae**

Eurymerodesmus dubius Chamberlin

Eurymerodesmus dubius Chamberlin, 1943, Proc. Biol. Soc. Washington, 56: 38.

Locality.—ARKANSAS: Pike Co., Delight. A male and an immature specimen taken April 16, 1941, by K. P. Schmidt.

Eurymerodesmus melacis Chamberlin and Mulaik

Eurymerodesmus melacis Chamberlin and Mulaik, 1941, Journ. New York Ent. Soc., 49(1): 59.

Locality.—TEXAS: Uvalde Co. A male and female taken April 7, 1937, by K. P. Schmidt.

Eurymerodesmus schmidti Chamberlin

Eurymerodesmus schmidti Chamberlin, 1943, Proc. Biol. Soc. Washington, 56: 38.

Locality.—ARKANSAS: Polk Co., Rich Mt., at 2,500–2,800 ft. Four specimens taken Mar. 21–22, 1938, by K. P. Schmidt.

Family **Euryuridae**

Amplinus eutypus, new species

Fig. 35

Dorsum in the preserved specimens light brown to greyish, with outer part of keels yellow. Legs yellow proximally in some, more brownish distally. Antennae and head yellow.

Collum almost symmetrically narrowed laterally, anterior and posterior margins about equally arcuate but the caudal a little incurved at middle while the corresponding part of the anterior margin is a little convex; surface tessellated, with the four transverse series of polygonal areas distinct across middle as well as laterally; a single elongate tubercle adjacent to lateral thickened border of keel.

Keels of segments 2 to 4 with posterior corner rectangular, the anterior corner produced laterad in a tooth and the lateral margin

caudad thereof sinuous or crenate, with three low crenatures which are also evident on the following keels excepting the poriferous ones in which more or less obscured. The keels are shorter in the antero-posterior direction than the middle part of metatergite; caudal margin in most running a little cephalad of ectad and then incurved adjacent to the corner which is but little produced in a blunt tooth into which the callus on the poriferous segments extends. Metatergites of anterior segments with the usual three series of raised polygonal areas which extend out on the keels to the thickened rim. In going caudad the number of rows of tubercules quickly increases to four and then to five; well developed tubercules also present on tergite 19.

Anal tergite of the usual form. Anal scale with median part of caudal margin straight, the lateral tubercles broad but low.

Width, 6 mm.

Locality.—MEXICO: Vera Cruz, El Fortin. Three females taken by H. Dybas on July 8, 1941, at 3,000 ft.

Amplinus leon, new species

Fig. 37

Dorsum light brown, keels of collum and next two or three segments entirely yellow, but on most keels this color is chiefly confined to the lateral border though tending to extend more or less along the anterior border. Last tergite yellow. Legs and antennae yellow.

Collum with lateral ends rather blunter than usual; as a whole strongly hemispherical with the convexity caudad and the anterior margin weakly arcuate or nearly straight; on dorsal surface a series of polygonal areas along anterior and posterior borders, with three series between these composed of areas only weakly defined; mesad of the thickened rim three areas in a sublongitudinal series.

In the keels of the immediately following segments the sides are straight, the anterior margin convex and the posterior margin a little incurved toward outer ends. In going caudad the posterior corner becomes more produced, with the adjacent caudal margin denticulate, but the process never long or distally slender and incurved in comparison, *e.g.*, with *A. schmidti* or *A. homochromus*. The tubercles of dorsal surface sharply set off by deep intervening sulci and strongly elevated; tubercles in three series on segments of the posterior half or more of the body. The tergite of the 19th segment also with five series of well developed tubercles.

Anal tergite of typical form, the four caudal crenatures as usual; basal portion of dorsal surface smooth. Anal scale with caudal corner protuberances unusually large, the intervening caudal margin comparatively short and straight (fig. 37).

Width, 7.2 mm.

Locality.—MEXICO: Nuevo Leon, Monterey. Female holotype taken by H. Dybas on June 15, 1941.

Amplinus orphnius Chamberlin

Amplinus orphnius Chamberlin, 1922, Proc. U. S. Nat. Mus., 60(5): 42, pl. 16, fig. 8.

Locality.—GUATEMALA: Escobas, Izabel. Two males, one female and one immature taken Nov. 27–30, 1933, by K. P. Schmidt.

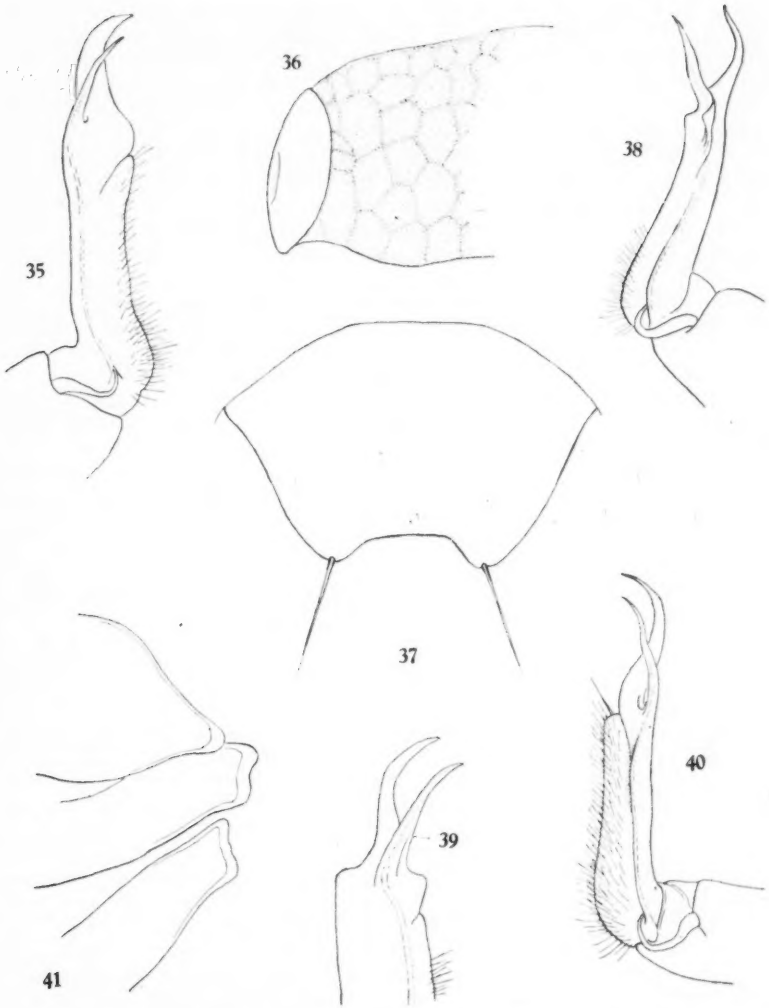


FIG. 35. *Amplinus eutypus*, n. sp. Gonopod, mesal aspect. FIG. 36. *Amplinus fortinus*, n. sp. Left keel XVI. FIG. 37. *Amplinus leon*, n. sp. Anal scale. FIG. 38. *Amplinus schmidti*, n. sp. Right gonopod, mesal aspect. FIG. 39. *Amplinus tajumulco*, n. sp. Distal end of gonopod, mesal aspect. FIG. 40. *Amplinus zuniulus*, n. sp. Right gonopod, mesal aspect. FIG. 41. *Colomborus martanus*, n. sp. Right part of collum and of second and third tergites.

Amplinus tajumulco, new species

A broad longitudinal yellow band embracing most of the width of the dorsum and including all of the last tergite, the sides of the dorsum and pleurae chocolate colored, the color deeper on the prozonites than on the metazonites and more chestnut on keels than on adjacent part of dorsum. Legs and antennae light chestnut. Vertex of head chocolate colored, verging down front to yellow on clypeus.

Collum strongly but not symmetrically narrowed at each side, the anterior margin weakly arcuate and the posterior very strongly convex at the middle; middle area of plate smooth, but on each side four rows of moderately elevated areas are evident, these reducing laterad first to three rows and then to two adjacent to the thickened lateral rim.

Keels of second and third segments a little bent forward, the anterior corner rounded, the posterior rectangular; the lateral margin of these and all other keels smooth, with no tooth at anterior corner. In middle region the posterior margin of keels runs a little caudad of ectad, making the corner gradually more acute but with no true process resulting except on the 19th segment. Three rows of polygonal areas on all segments, including the 19th, the areas of anterior row tending to be poorly defined, especially those at middle part.

Last tergite smooth, widest toward caudal end; crenatures of the caudal margin low or obscure. Anal scale trapeziform, the caudal margin wide and straight, with the corner setae sessile or nearly so.

Gonopods as drawn (fig. 39).

Width, 7.2 mm.

Locality.—GUATEMALA: Volcan Tajumulco. Holotype male taken by K. P. Schmidt June 16, 1936, in a bromeliad.

Amplinus schmidti, new species

Fig. 38

Dorsum dark chocolate colored to nearly black, with prozonites and sides somewhat lighter; borders of keels yellow, this color commonly also along mesal side of the thickened lateral rim both above and below and extending along caudal margin of keel only; apical part of last tergite also yellow. Legs and antennae light brown.

Collum of typical form, the keels rather narrow; dorsal surface on each side showing five rather irregular rows of areas which are not strongly elevated or sharply separated from each other; on each keel two large tubercles mesad of the thickened lateral rim, the inner of these a little forward of directly mesad of the outer one.

On the ordinary metatergites the posterior corners are conspicuously extended into processes that end in an acute tip which is incurved, with mesal margin of the processes denticulate. Surface tessellated, the polygonal areas in three transverse rows, with the areas of the middle series larger than those of the other two rows. On the eighteenth and nineteenth tergites the tubercles form elongate areas or rugae which are more sharply developed on the eighteenth; the posterior processes of the tergites with tips not incurved or uncate, those of the nineteenth in particular rounded.

Anal tergite with caudal margin convex, presenting two large

crenatures at middle and a smaller one ectad of each of these just mesad of the corner seta; basal portion not transversely wrinkled. Anal scale of the usual trapeziform shape, the caudal margin slightly re-entrant at middle with the setiferous tubercle at each end well developed.

Gonopods as drawn (fig. 38).

Width, 5.25 mm.

Locality.—GUATEMALA: Volcan Tajumulco. Male holotype and two females taken by K. P. Schmidt Feb. 13, 1934. (Mandel Expedition.)

Amplinus zuniulus, new species

Fig. 40

Dorsum brown of a slightly chestnut cast, with the keels and anal tergite, except at base, entirely yellow. Legs yellow. Antennae yellow, darker distally.

The collum symmetrically narrowed on each side, the anterior and posterior margins about equally bowed; surface smooth, with polygonal areas developed only on and immediately adjacent to keels.

Keels of first three segments with anterior corners rounded and presenting a slight denticle above on latter; posterior corners subrectangular.

On subsequent segments the anterior margin of keels convex, the posterior in processing caudad becoming gradually more and more concave, making the posterior corner more acute but never forming a true process, the general form being nearly as in *tajumulco*. Three rows of polygonal areas which are obscure over middle part of dorsum of the anterior segments and only those of the posterior row indicated on the 19th tergite.

Anal tergite moderately long, its surface smooth except a median longitudinal groove; lateral borders thickened. Anal scale trapeziform, its caudal margin straight and the corner setae sessile; sides convex.

Gonopods as drawn (fig. 40).

Width, 6 mm.

Locality.—GUATEMALA: Pinca Monte Cristo, Volcano Zunil. Holotype male taken by Dr. J. Steyerm Jan. 31, 1940.

Auturus mimetes Chamberlin

Auturus mimetes Chamberlin, 1942, Bull. Univ. Utah, Biol. Ser., 6(8): 8, fig. 21.

Localities.—ARKANSAS: Logan Co., Mt. Magazine at 2,500 ft., a male and female taken Mar. 24, 1938, by K. P. Schmidt. 14 mi. N. of Silva, a male and female taken by J. M. Schmidt, April 14, 1941.

This species was previously known from Missouri.

Auturus phanus Chamberlin

Auturus phanus Chamberlin, 1942, Bull. Univ. Utah, Biol. Ser. 6(8): 7, fig. 20.

Locality.—LOUISIANA: Camp Wilson, B.S.A., Indian Mound. A male taken by A. C. Wood, Aug. 4–7, 1923.

Previously known from Greenburg in the same state.

Genus **Colomborus,** new

Segments and pores normal.

Dorsum strongly arched, bearing large tubercles or elevated areas laterally and obscure ones along borders of median portion, elsewhere smooth.

Caudal tergite broad, its caudal margin widely convex. Anal scale convex between the tubercles.

Bearing prominent processes on the fifth and sixth sternites in the male.

In the gonopods the acropodite is in the form of a transversely placed, semicircular lamina from the base of which arises the slender, typically bent, solenomerite and from the middle part of which projects proximad a stout spine.

Generotype.—*Colomborus martanus* n. sp.

This genus is probably most nearly related to the Peruvian *Ptyxogon*.

Colomborus martanus, new species

Figs. 41, 42

Dorsum brown to maroon, with the keels yellow or in darker individuals verging toward red. Legs light brown. Antennae brown, with distal articles chestnut.

Vertex of head smooth, the median sulcus lying in a furrow that widens between antennae. Clypeus limited above by a transverse furrow; foveolae 2–2.

Collum with keels narrowed laterad and narrowly rounded at ends, anterior margin straight over middle part or but slightly convex, the posterior margin widely but only slightly concave; elevated polygonal areas or large tubercles present at bases of keels but these obscure or absent over middle region (fig. 41).

Dorsum between keels strongly convex, almost semicircular in cross section. Keels of segments 2 to 4 with lateral margins smooth, weakly incurved at middle; anterior margin a little convex, the posterior incurved, with caudal corner a little produced on fourth keels, and on subsequent ones gradually becoming more prominent. Surface of metazonites showing large tubercles toward the keels but the middle region lacking them excepting a series of low and partly obscure ones along the caudal border.

Anal scale proportionately wide, with margin convex between the tubercles. Anal tergite normal.

The gonopods as represented in fig. 42.

Width, 5.5 mm.

Locality.—COLOMBIA: Region of Santa Marta and Manzanaris on the Rio Ronda. Eight specimens, including male holotype, taken in July-August, 1902, by H. N. Howland.

Genus **Euplinus,** new

Differing from *Amplinus* primarily in having the tibiotarsal division of the male gonopods composed of two long slender branches instead of being entire.

Generotype.—*Euplinus volcanicola* n. sp.

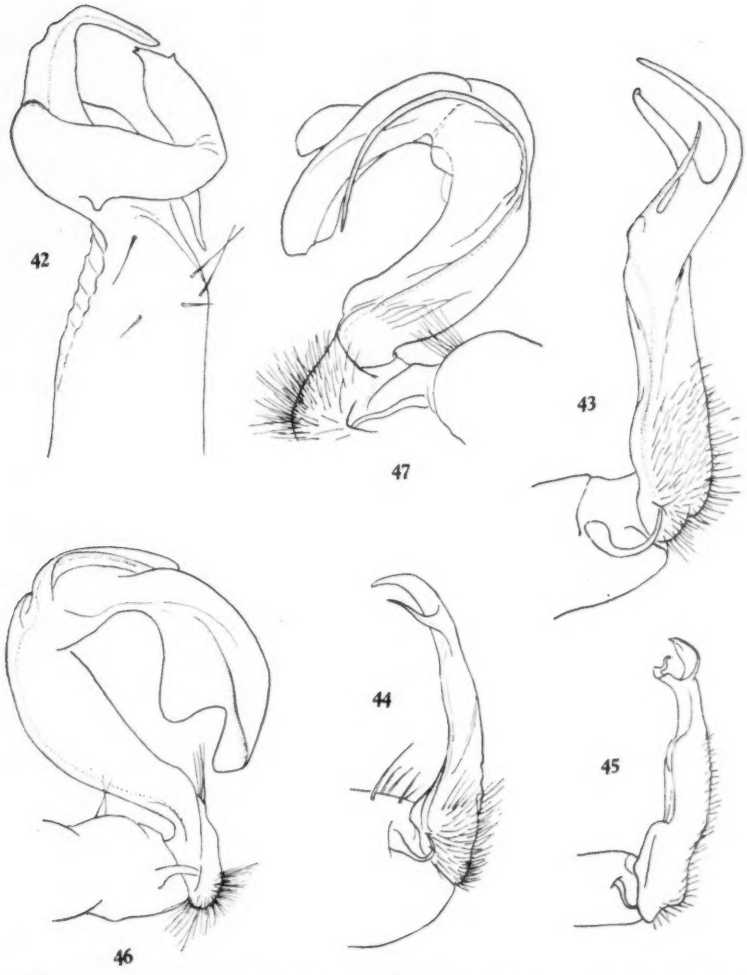


FIG. 42. *Colomborus martanus*, n. sp. Distal part of gonopod viewed in situ. FIG. 43. *Euplonus volcanicolens*, n. sp. Left gonopod, mesal aspect. FIG. 44. *Aymaresmus tambonus*, n. sp. Left gonopod, mesal aspect. FIG. 45. *Platyrrhacus calius*, n. sp. Left gonopod, mesal aspect. FIG. 46. *Nearctoma araguanum*, n. sp. Gonopod, ventromesal aspect. FIG. 47. *Nearctoma cuzconum*, n. sp. Right gonopod, ventromesal aspect.

Euplinus volcanicola, new species

Fig. 43

Entire body together with head, legs and antennae a nearly uniform brown without lighter markings, but dorsum of a duller, somewhat greyish brown cast, the legs brighter.

Collum with keels swollen at ends; surface tessellated on each side of the middle area, the elevated areas being in three series and extending out on keels to the terminal swelling.

On the following tergites the posterior corners of the keels are strongly and characteristically produced caudad, the tips of the processes acute and curved mesad. The dorsal surface of metatergites strongly tessellated, the areas of the caudal series smaller than the others. On the anterior segments the tubercles are in three rows, but farther back they form first four series and then, on the seventeenth, five. On the 19th tergites the tubercles are in the form of narrow, elongate areas on the posterior part of the plate, the anterior half of which is smooth; the keels of this tergite apically rounded.

The anal tergite with the two paramedian crenatures on caudal margin more prominent; basal part transversely wrinkled.

Gonopods represented in fig. 43.

Width, 9 mm.

Localities.—GUATEMALA: Volcan Tajumulco, male holotype and female allotype taken Feb. 21, 1934, by K. P. Schmidt at El. 6,300 ft. El Porudnir, San Marcos, a male taken by K. P. Schmidt Mar. 5, 1934. (Mandel Expedition.)

Family **Platyrhacidae**

Aymaresmus tampocus, new species

Fig. 44

Differing conspicuously in coloration from all species of the genus heretofore known in having the entire dorsum, inclusive of the keels, yellow with the exception of a narrow, sharply defined, longitudinal black stripe over bases of keels and adjacent border of tergites, and a median dorsal brown line. Sides of segments also black, with venter the same or somewhat more brownish or chestnut. Head and antennae black or nearly so. Legs chestnut.

Head strongly rugose above; on frontal area two pairs of stout setae, the two lower setae the more widely separated; clypeal setae six.

Collum subhemispherical in outline, with the convexity behind; anterior margin straight except toward ends where curving; not margined; a series of low tubercles across anterior border, the rest of the surface covered with small polygonal areas, those along caudal border larger and longitudinally elongate.

Keels of segments 2 to 4 inclusive narrowing a little from base outward; the lateral margin smooth or scarcely wavy, with both corners well rounded. On keels of the subsequent segments the anterior margin becomes more nearly straight rather than convex and is set off by a submarginal sulcus and is distinctly finely denticulate; the posterior corner becomes gradually rectangular and farther back

acutely produced caudad; the processes on the 18th keels blunter and on the 19th widely rounded. The surface of all metatergites entirely covered with a network of impressed lines setting off small polygonal areas or flat tubercles which are more elevated and more truly tubercle-like on the keels where they are evident in three rows. Pores removed from lateral margin by two or three times their diameter.

Anal tergites at free end strongly convexly rounded and crenate. Anal scale with median angle acute, exceeded by the two stout setiferous tubercles.

Gonopods as represented in fig. 44.

Length, about 55 mm.; width, 9.2 mm.

Locality.—PERU: Poco Tambo. Male holotype taken by W. H. Osgood and M. Anderson on June 29, 1912.

Platyrhacus callius, new species

Fig. 45

Color uniform brown with lighter stripes or other markings. Legs and antennae also brown.

Vertex of head finely granular.

Collum with anterior margin nearly straight; posterior margin strongly convex; the two margins converging acutely at each end. Dorsal surface densely coarsely granular, with two or three tubercles projecting at each end. A transverse depression back of the anterior border.

On the ordinary tergites the surface is similarly densely coarsely granular and shows among the granules three transverse series of widely separated somewhat larger tubercles, those on the caudal border more numerous and distinct. Keels of moderate width; lateral margin bearing mostly six well separated teeth. The pore close to the lateral margin, facing dorsolaterad.

Last tergite with part beyond the somewhat narrowed base semicircular in outline, with the margin essentially smooth, being free of teeth or tubercles; dorsal surface finely granular.

Gonopods with the telopodite straight, not distally bent or curved; the solenomerite sinuous (fig. 45).

Width, 9 mm.

Locality.—COLOMBIA: Cali. Male holotype, June 30, 1947, H. Dybas collector.

Family **Pratinidae** Schubart

Aphelidesmus major, new species

The preserved female type of this species shows a broad longitudinal band of grey color extending from head to and including the last tergite, with keels of the same color; between the keels and the middorsal band the dorsum is brown. Legs and antennae dull yellowish.

Median sulcus across vertex deep, anteriorly furcate and ending in a pit or depression between the antennae. A rounded median swelling on face just below this depression, this bearing two setae at its upper part, with a seta ventroectad of its lower end on each side.

Clypeal setae 2–2 ectad of the ordinary series of labral setae two larger submarginal setae.

Collum with posterior margin strongly arcuate but middle part nearly straight; the anterior part more strongly convex, with the curvature even excepting for a little increase at base of keel; caudal corner of keel rectangular, the anterior corner well rounded.

Keels of the second and third segments running a little forward of ectad; anterior corner rounded, the posterior subrectangular; the anterior margin convex, the posterior slightly concave. On keels of the fourth segment the incurving of the caudal margin more pronounced, the margin on this and the other keels finely and closely denticulate as is also the anterior margin, but the lateral margin smooth. On the fifth and subsequent segments the posterior corner of the keels is extended into a process which is distally incurved excepting on keels of the 18th and 19th segments where the process is shorter and that of 19th especially distally rounded. The dorsum of all segments strongly convex, with the keels nearly evenly continuing its curvature. Surface of all tergites smooth and shining.

Anal scale semicircular, the posterior margin but little flattened; caudal seta on each side arising from a dimple or foveola. Inner borders of anal valves moderately thickened and set off; with the usual two setae. Last tergite with the usual form and setae.

Length, 64 mm.; width, 10 mm.

Locality.—GUATEMALA: Escobas, opposite Puerto Barrios. Female holotype taken by K. P. Schmidt on April 18, 1934. (Mandel Expedition.)

Distinguishable by its large size and especially its color pattern.

Family **Strongylosomidae**

Genus **Nearctoma,** new

Segments normal in number. Pores normal in number and distribution.

The pores opening on the sides of lateral swellings that represent the keels.

Keels on the second segment lower than the others.

None of the legs or sternites with special processes or other modifications in the male. All tarsi densely scopulate beneath.

In the gonopods of the male the tibiotarsus is set off from the femur. The solenomerite is a slender styliform process lying against or in a groove in the large tibiotarsal lobe; seminal channel running in a direct course to the solenomerite.

Generotype.—*Nearctoma cuzconum* n. sp.

Nearctoma araguanum, new species

Fig. 46

Body chestnut above and on the sides, the venter yellow. Legs and antennae also light chestnut, with coxae and tarsi yellow.

Sulcus on vertex deep. Head over vertex and on face moderately roughened, with rather sparse setae on face up to level of antennae, and a single seta on vertex each side of anterior part of sulcus.

Collum nearly symmetrically narrowed laterad on each side to a well rounded end; median part of both anterior and posterior margins straight or nearly so; surface roughened with irregular tubercles and short rugae.

The keel of second tergite in the form of a narrow, line-like, ridge which is situated well below the level of the other keels. On segments 2 to 4 the keels are represented by slight, smooth swellings limited above by a sharply impressed sulcus. On the subsequent segments the keels are similarly set off above by a sulcus, thicker and more distinct at posterior end than at its anterior. Surface of metatergites irregularly roughened above, the side also roughened with small tubercles and granules of which two at base of legs are larger and conspicuous. Pleural keels distinct, in the form of low, smooth, line-like ridges.

Last tergite beyond the basal ring subcylindrical, but little narrowing to the blunt end, moderately exceeding the valves. Anal valves narrowly margined along mesal border. Anal scale convexly rounded behind.

Legs with tarsi densely scopulate beneath. Sternites of normal width; with no special modification in the male.

In the gonopods the telopodite is curved into a circle which lies in a nearly transverse plane, curving first ectad and then mesad and caudad, the tip of the tibiotarsal lobe nearly touching the base of the femoral division. Tibiotarsal lamina expanding clavately distad, divided into two lobes at distal end. The solenomerite a slender style lying in a groove on the convex side of the tibiotarsal lobe (fig. 46).

Width of male, 2.8 mm.

Locality.—VENEZUELA: Hacienda la Trinidad, near Maracay, state of Aragua. Male holotype and female allotype collected by Padre Cornello Vogl.

Nearctoma cuzconum, new species

Fig. 47

In this species the sides above are dull chestnut brown, with the lower sides and a broad median dorsal stripe nearly white, but this band interrupted by a narrow deeper chestnut stripe encircling caudal border of each tergite. Legs and antennae and head also chestnut.

The head with numerous short setae on lower part of face and a series of two or three setae each side of the anterior end of the sharply impressed verticial sulcus.

Collum with ends widely rounded; anterior margin widely convex, the posterior a little incurved at middle; dorsal surface smooth, with a series of six widely separated setae along anterior border and a similar series of six setae across the middle.

The keels of the second segment represented by a sharply raised edge below level of the other keels. On subsequent segments the keels are marked by a sharply impressed sulcus below which there is a low, broad and smooth swelling on which the pores open laterally on the poriferous segments. On all metatergites a transverse series of four widely spaced setae. Pleural keels in form of distinct raised lines.

Anal tergite smooth, its cauda produced well beyond the valves, its end bluntly rounded. Anal scale wide, its caudal margin showing a very obtuse angle at the middle.

Sternites and legs not showing secondary modifications in the male.

In the gonopods of the male the solenomerite is longer and more exposed than in ***araguanum***, with the secondary lobe of the tibiotarsus on the outer side and more toward the convexity rather than on the concave side as it is in the other species. See, further, fig. 47.

Width, 2.2 mm.

Locality.—PERU: Hacienda Urco, near Calca, Cuzco. Male holotype taken Sept. 15, 1939, by K. P. Schmidt at an elevation of 9,500 ft. (Museum Magellan Expedition.)

Oxidus gracilis (C. L. Koch)

Fontaria gracilis C. L. Koch, 1847, *in* Koch-Panzer, Krit.-Rev. der Insektenfauna Deutschlands, vol. 3, p. 142.
Oxidus gracilis Cook, 1911, Proc. U. S. Nat. Mus., 40: 63.

Localities.—CALIFORNIA: Los Angeles, Oct. 29, 1935, and Jan., 1936, four specimens taken by G. Grant. San Diego, Balboa Park, Sept., 1940, many specimens taken by Morton Moran.

Asiomorpha coarctatum (Saussure)

Polydesmus coarctatus Saussurem, 1860, *in* Mém. Soc. Genève, 15: 297, pl. 18, fig. 18.
Orthomorpha coarctata Pocock, 1895, Ann. Mus. Genova, 34: 809.
Asiomorpha coarctata Verhoeff, 1939, Zool. Anz., 127: 117.

Locality.—HAITI: Near St. Mark, Dec. 6, 1928, K. P. Schmidt collector. (Crane Field Museum Expedition.)

REVISION GENERALE DES HARPALINAE D'AFRIQUE ET DE MADAGASCAR (COLEOPTERA, CARABIDAE), by P. BASILEWSKY. Ann. Mus. Congo Belge Tervuren (Belgique). Ser. in 8°, Sci. Zool. vol. 6, 1950, 283 pp., 200 figs., IX plates; Vol. 8, 1951, 333 pp., 191 figs., VI plates.

This splendid work on the Harpalinae (equivalent to the Harpalini of LeConte) of Africa south of the Sahara desert contains keys and descriptions to 66 genera and 492 species. Figures are given of 60 species in dorsal view and of the lateral and sometimes the dorsal view of the aedeagus of about 387 species. Frequently the aedeagus is figured without being described in either the key or the description and the species are not, in general, distinguished primarily on aedeagal characters. Of the 492 species, nearly a third (143 species) have been described by Basilewsky himself, many of them for the first time in the present monograph, a figure that suggests that there are many Ethiopian species of the group still to be discovered. Of the remaining 349 species, over half were described by four coleopterists: Dejean, 54 species; Jeannel, 52 species; Peringuey, 47 species; and Burgoon, to whom the present work is dedicated, 36 species.

The reviewer notes with approval that the author, in contradistinction to many taxonomists, adopts a style of key that enables the genera and species in the key to be in the same sequence as that adopted in the text.

—MELVILLE H. HATCH.

STUDIES ON ARTHROPOD CUTICLE. IX. QUANTITATIVE EFFECTS OF DIET, AGE, TEMPERATURE AND HUMIDITY ON THE CUTICLES OF FIVE REPRESENTATIVE SPECIES OF INSECTS[1, 2]

CHING-HSI TSAO AND A. GLENN RICHARDS
Division of Entomology and Economic Zoology,
University of Minnesota

The published quantitative determinations of percentages of cuticle and of cuticular components have recently been tabulated by Richards (1951). Large differences are found between different species and even between different stages of the same species. However, these published data do not show whether the percentages vary significantly between different individuals of a species at any one particular age. And, further, the published data do not show whether percentage differences exist between large and small individuals, or whether variations can result from environmental differences. The present paper is a contribution towards answering the above questions.

This paper is a condensation of a thesis submitted by C. H. T. in partial fulfillment of the requirements for the degree of Doctor of Philosophy. The original thesis contains full tabular data for all the determinations made. This thesis, on file in the Entomology Library of the University of Minnesota, may be obtained on interlibrary loan by anyone interested in the details of each individual analysis.

MATERIALS AND METHODS

Five species of insects were used in these studies: the oriental cockroach, *Blatta orientalis* L., the confused flour beetle, *Tribolium confusum* Duv., the yellow mealworm, *Tenebrio molitor* L., the wax moth, *Galleria mellonella* (L.) and a blowfly, *Phormia regina* (Mg.). Laboratory cultures of the above species were used as stocks from which eggs, newly hatched larvae or nymphs, and newly emerged adults were obtained for the studies given under each species. None of the tests were under sterile conditions. All feeding was *ad libitum* on an excess of food.

The method of preparation depended on the type of determination to be made. In some cases the entire insect was treated with alkali for chitin purification, but in most cases the cuticle was isolated manually by dissection followed by careful scraping with a small piece of

[1]Paper No. 2793, Scientific Journal Series, Minnesota Agricultural Experiment Station, University of Minnesota, St. Paul 1, Minnesota.

[2]The work described in the present paper was performed under contract between the Office of the Surgeon General, U. S. Army, and the University of Minnesota. Under the terms of this contract the Army neither restricts nor is responsible for the opinions and conclusions of the authors.

cheesecloth under a microscope. When water content was to be determined, the cleaning was performed in liquid paraffin (Dennell, 1946), but when the cuticles were to be used only for dry weight determinations the cleaning was done in water to avoid trace contaminations of oil. The isolated cuticles were then dried to constant weight at 100° C.

For purification of chitin, isolated cuticles were treated with a 10% NaOH solution at 100° C. in Pyrex tubes closed with Bunsen valves (Campbell, 1929) for a period of time determined by preliminary analyses as necessary for obtaining constant weight for the particular type of cuticle being studied. (Fraenkel & Rudall, 1947; Lafon, 1943 a-c.) When purification required several days, changes to fresh solutions were made. Intact insects were treated similarly after being opened except that they were treated with 5% NAOH solution, or 5% solution followed by 10%. Residues were located under a dissection microscope, and then passed through 95, 70, 50 and 25% ethyl alcohol to dilute HC1 (about 0.4%) for 10 minutes, and finally soaked in distilled water for about 24 hours prior to drying.

Preparation of chitosan was similar except for using concentrated KOH solutions at 160° C. (Campbell, 1929; Tauber, 1934) and omitting the wash with dilute acid which would dissolve the chitosan.

Tests for reproducibility of determinations were made by cutting cleaned cuticles of *Galleria* larvae longitudinally, and making separate determinations for each half. Reproducibility as determined in this manner was found to be about 4% (average 2.8%).

Larger samples were weighed on a standard analytical balance reading to 0.1 mg.; samples weighing less than 30 mg. were weighed on a Roller-Smith Model C Precision Torsion Balance which could be read reliably to 0.01 mg. After oven-drying, samples were stored in a desiccator, and weighed later on days when the humidity of the laboratory was low.

RESULTS

Comparison of Chitin and Chitosan Determinations

Twenty pairs of half larvae of *Galleria* purified for chitin for periods of two to eight days showed deviations up to 3.9% (average 2.4%) when the two halves were treated for the same period of time (4 days), but deviations up to 6.8% (average 2.5%) when the time of treatment was different. Similarly, eighteen pairs of half larvae purified and simultaneously transformed into chitosan for periods of thirty to ninety minutes showed deviations up to 4.6% (average 1.7%). It appears, then, that a similar degree of reproducibility may be obtained for chitin and chitosan determinations. But perhaps the chitosan determinations require more experience because in our preliminary tests greater deviations were encountered in chitosan estimates.

A separate set of tests were performed to determine whether the conversion of chitin to chitosan is quantitative and complete. Ten half-pairs of *Galleria* larvae were purified for chitin, the other ten half-pairs were purified for chitosan. The ratio of chitosan to chitin was found to range from 74.1 to 88.2% with an average of 78.7%. Similarly, twelve samples of chitin previously purified from *Galleria* cuticles

were converted to chitosan with resulting ratios ranging from 73.4 to 81.6% with an average of 77.6%. These ratios are not appreciably different from the theoretical ratio of 79.32 which is based on the assumption of complete deacetylation of the chitin chains (see Richards, 1951).

Comparable results have been reported for chitin determinations from hard, sclerotized cuticles (Fraenkel and Rudall, 1947; Richards, 1951). However, attempts to make chitosan determinations directly from sclerotized cuticles of *Tenebrio* larvae and *Blatta* adults gave impossibly high ratios indicating incomplete purification of the chitosan when only concentrated KOH solutions are used (Richards, 1949).

From the above data it is concluded that determinations can be made which are individually reproducible to within a few per cent, and that equally valid data may be obtained from determination of either chitin or chitosan. In the present study the determination of chitin was routinely made because most of the figures in the literature are for this, and because complications due to sclerotization are thus avoided. Unfortunately, there is at the present time no method for assessing the true accuracy of any method for quantitative chitin determination (Richards, 1951).

Effects of Age and Diet on the Cuticles of Blatta orientalis

Variation with age within the adult instar was studied by segregating adults at emergence and keeping them on the normal diet recommended by McCay and Melampy (1937) and at 27° C. and 70% R. H. Isolated abdominal tergites and sternites were used for determination of water and chitin percentages. Data are summarized in Table I. From these

TABLE I

CHITIN AND WATER CONTENTS OF ABDOMINAL CUTICLES OF *Blatta* ADULTS OF DIFFERENT AGES REARED ON NORMAL DIET

	No. of Samples	Av. Wet Body Wt. mg.	Isolated Cuticles		Chitin Dry Wt. mg.	Chitin Cuticle %
			Dry Wt. mg.	H_2O cont. %		
119-day old						
tergite, ♀	6	913.5	5.095	11.7	1.573	30.8 ± 1.28
sternite, ♀	6	do	3.609	9.0	1.312	36.2 ± 1.60
60–69-day old						
tergite, ♀	17	1035.9	5.440	13.5	1.585	29.4 ± 0.81
sternite, ♀	17	do	3.960	12.4	1.285	32.5 ± 0.59
5-day old						
tergite, ♀	12	654.9	3.328	9.4	0.583	28.2 ± 0.92
sternite, ♀	14	648.9	2.468	8.3	0.869	35.1 ± 0.94
tergite, ♂	11	373.1	1.104	7.2	0.405	36.8 ± 4.00
sternite, ♂	9	364.6	1.248	6.7	0.457	36.7 ± 2.13

data it can be seen that the chitin percentage of abdominal sclerites is about 15% higher in males than in females, and that at least in females the chitin percentage is about 17% higher in sternites than in tergites. However, the larger numbers averaged in Table IX show only about 8% difference for each of these. But there are no apparent percentage differences correlated with adult age; since the adults

increase considerably in weight there must be a corresponding increase in cuticle in this species.

It seemed desirable to check the last point above on entire insects rather than on just abdominal sclerites but satisfactory cleaning of the entire cuticle did not seem feasible. Accordingly chitin determinations were made from entire adult bodies; from these values figures for the cuticle were estimated assuming an average value of 31.9% for chitin in the cuticle of females, 35.8% for males. These values are graphed in fig. 1. The curves show clearly that the amount of chitin increases

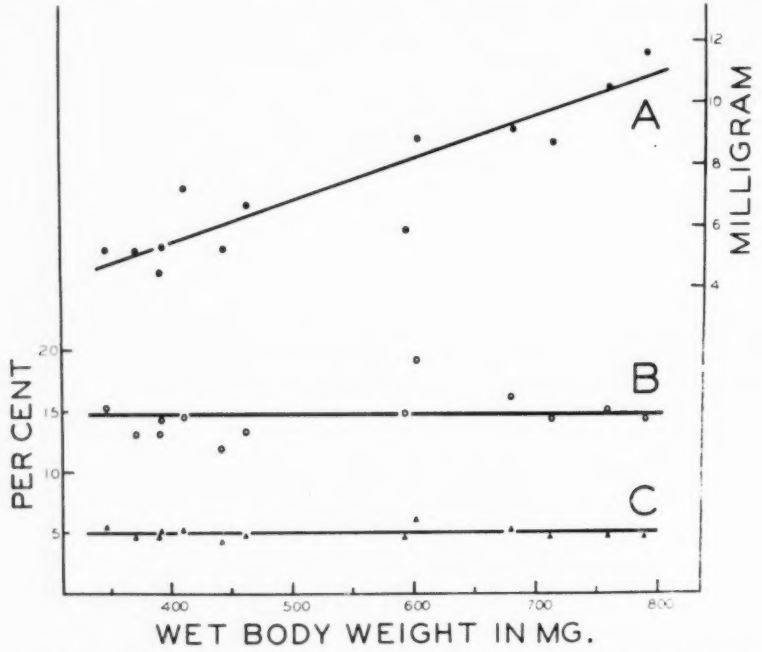


FIG. 1. Curves for chitin and cuticle content of adult *Blatta orientalis* as a function of size. Specimens in weight range 340–470 mg. were males; specimens in weight range 590–800 mg. were females.

A. Total chitin in milligrams.
B. Estimated percentages of dry cuticle to dry body weight.
C. Percentages of dry chitin to dry body weight.

with size (curve *A*) but that the percentage of chitin remains constant (curve *C*); presumably the calculated percentages of cuticle (curve *B*) are also correct in showing constancy.

To test the effects of diet, newly hatched nymphs were reared to maturity on three different diets, and determinations made on the abdominal sclerites of the adults obtained. The diets each contained whole wheat flour, skim milk powder and dried Brewer's yeast; the normal diet contained these ingredients in the ratio of 50 : 45 : 5, the low carbohydrate diet 20 : 80 : 5, and the high carbohydrate diet

90 : 10 : 5 by weight. The nymphs were allowed to feed *ad libitum* on an excess of food; they grew better on the high carbohydrate diet than on the low carbohydrate diet: respectively 62% of the 60 nymphs became adult within an average of 126 days as opposed to 53% of the 60 nymphs becoming adult in an average of 151 days. Also the adults were slightly heavier when reared on the high carbohydrate diet. Data are summarized in Tables II and III. No significant differences

TABLE II

CHITIN AND WATER CONTENTS OF ABDOMINAL CUTICLES OF 5-DAY OLD *Blatta* ADULTS REARED ON MODIFIED DIETS

	No. of Samples	Av. Wet Body Wt. mg.	Isolated Cuticles		Chitin Dry Wt. mg.	Chitin Cuticle %
			Dry Wt. mg.	H_2O cont. %		
High carbohydrate diet						
tergite, ♀	12	802.0	4.197	12.7	1.154	28.8 ± 1.24
sternite, ♀	13	796.0	3.040	12.5	0.981	32.7 ± 1.17
tergite, ♂	11	439.6	1.522	10.4	0.538	35.3 ± 2.18
sternite, ♂	12	440.4	1.798	10.2	0.636	35.8 ± 1.61
Low carbohydrate diet						
tergite, ♀	7	726.7	3.935	12.8	1.238	31.3 ± 0.42
sternite, ♀	7	726.7	2.716	13.0	0.941	34.4 ± 1.31
tergite, ♂	9	418.9	1.269	10.0	0.414	32.9 ± 1.32
sternite, ♂	7	421.7	1.631	12.8	0.609	37.3 ± 0.84

TABLE III

CHITIN AND ESTIMATED CUTICLE PERCENTAGES OF FIVE-DAY OLD *Blatta* ADULTS REARED ON DIFFERENT DIETS

	Determined Values			Estimated Values		
	Av. Wet Body Wt. mg.	Chitin Wet Body %	Chitin Dry Body %	Dry Cut. Wet Body %	Dry Cut. Dry Body %	Wet Cut. Wet Body %
FEMALE:						
Normal diet	637.9	1.25(8)[a]	5.12(4)	3.95	16.2	.....
Low carbohydrate diet	728.1	1.53(6)	.....	4.82	.....	.....
High carbohydrate diet	736.9	1.44(4)	4.66(2)	4.54	14.7	.....
Average	.....	1.42	4.89	4.44	15.5	5.02[b]
MALE:						
Normal diet	399.4	1.42(7)	4.90(5)	3.39	13.7	.....
Low carbohydrate diet	399.5	1.76(4)	4.96(2)	4.91	13.9	.....
High carbohydrate diet	431.8	1.62(4)	.....	4.53	.....	.....
Average	.....	1.60	4.93	4.28	13.8	4.75[b]

[a] Figures in parentheses indicate the number of determinations made.
[b] Values calculated from percentage of dry cuticle to wet body weight.

correlated with quality of diet were found; differences in diet produce large differences in body weight and some difference in growth rate but the amounts of chitin and cuticle increase proportionately with the result that the percentage values remain constant (Fig. 1).

Effects of Diet on Larval and Adult Cuticles of Tribolium confusum

This beetle is particularly interesting because it is known to be capable of growing in the complete absence of free carbohydrate.

TABLE IV

CHITIN CONTENT OF *Tribolium* LARVAE REARED ON DIFFERENT DIETS

	Diet without Glucose	Diet with Glucose
Number of samples[a]	5	5
Average wet body wt., mg	1.952	2.175
$\frac{\text{Dry cuticle}^b}{\text{Wet body wt.}}$ %	5.15	5.29
$\frac{\text{Chitin}^b}{\text{Dry cuticle}}$ %	21.88 ± 0.99	23.81 ± 0.74
$\frac{\text{Chitin}^b}{\text{Wet body wt.}}$ %	1.13 ± 0.04	1.26 ± 0.06
$\frac{\text{Dry cuticle}^b}{\text{Dry body wt.}^c}$ %	11.6	11.8
$\frac{\text{Chitin}^b}{\text{Dry body wt.}}$ %	2.5	2.8

[a]Each sample consisted of two larvae.

[b]Not including the cuticle and chitin of head capsules, the dry weight of which is so small that it was neglected.

[c]The dry body weight was calculated from wet body weight and a water content of 55.5%, which was determined from 30 mature larvae reared on whole flour at 27° C. and 70% R.H.

Newly hatched larvae were reared at 35° C. and 75% R. H. on diets containing glucose, casein (vitamin test brand), dried Brewer's yeast, MacCallum-Davis Salt Mixture No. 185 and cholesterol in proportions by weight of 50 : 50 : 5 : 2 : 1 and 0 : 100 : 5 : 2 : 1. Controls were reared on flour plus yeast.

Data from mature larvae are presented in Table IV. No significant differences correlated with diet were found.

Data from adults are presented in Table V. The differences in larval diet do not seem to affect the percentage of chitin in relation to the fresh weight of adult beetles, but, correlated with higher water content, the percentage of chitin in relation to dry body weight was significantly higher for adults reared on the diet containing glucose. The presence of glucose in the larval diet raises the chitin percentage of the adult less than 10%; it has no significant effect on the percentage in the larva. The experiments were not run under sterile conditions but it is still necessary to conclude that this species under natural

conditions synthesizes chitin about as readily in the absence of free exogenous carbohydrate as in its presence. However, it should be remembered that casein on hydrolysis yields some glucosamine (Nilsson, 1936); our experiments do not demonstrate ability to synthesize the monosaccharide unit.

TABLE V

CHITIN CONTENT OF ONE-DAY OLD *Tribolium* ADULTS REARED FROM DIFFERENT DIETS

	Diet without Glucose	Diet with Glucose	Sieved Flour with 5% Yeast[a]
No of samples[b]	10	10	9
Average wet body wt., mg	1.571	1.686	1.951
Water content of adult, %	57.7	60.6	56.5
$\frac{\text{Chitin}}{\text{Wet body wt.}}$ %	2.86 ± 0.127	2.92 ± 0.044	2.87 ± 0.058
$\frac{\text{Chitin}}{\text{Dry body wt.}}$ %	6.78 ± 0.183	7.41 ± 0.164	7.00 ± 0.156

[a]This culture was kept at 30° C. and 75% R.H.; the other cultures were kept at 35° C. and 75% R.H.

[b]Each sample consisted of 4 adults.

Effects of Larval Diets on the Cuticles of Adult Tenebrio molitor

Larvae were reared at 27° C. and 70% R. H. on diets high and low in carbohydrate. The diets contained glucose, casein (vitamin test brand), dried brewer's yeast and MacCallum-Davis Salt Mixture No. 185 in proportions respectively of 80 : 20 : 5 : 1 and 20 : 80 : 5 : 1 by weight. Larval reared on the low carbohydrate diet grew more slowly and produced smaller adults but in percentage terms there was no significant difference in chitin content (Table VI). However,

TABLE VI

CHITIN CONTENT OF ONE-DAY OLD *Tenebrio molitor* ADULTS REARED ON DIFFERENT DIETS

	Low Carbohydrate Diet	High Carbohydrate Diet
Number of samples	6	20
Average dry body weight, mg	29.8	33.8
Average wet body weight[a], mg	88.4	100.3
$\frac{\text{Chitin}}{\text{Dry body wt.}}$ %	6.78 ± .385	7.15 ± .248
$\frac{\text{Chitin}}{\text{Wet body wt.}}$ %	2.24	2.40

[a]Wet body weight calculated from determination of 66.3% water in one-day old adults reared on whole wheat flour plus yeast.

considerable individual variation was encountered in the small number of specimens used (*e.g.* determinations of chitin/dry body weight ratios varied from 5.5 to 10.4 with an average individual variation of 10% from the 7.1 average).

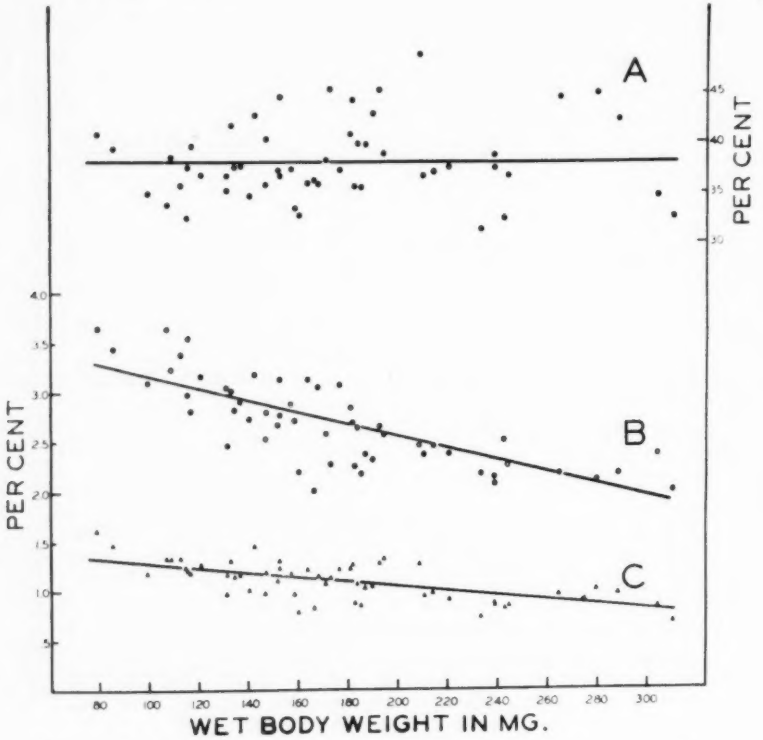


FIG. 2. Curves for chitin and cuticle of *Galleria mellonella* larvae as a function of size.
A. Percentages of dry chitin to dry cuticle.
B. Percentages of dry cuticle to wet body weight.
C. Percentages of dry chitin to wet body weight.

Effects of Temperature and Humidity on the Larval Cuticles of Galleria mellonella

Larvae were reared on Haydak's formula (1943) but with the honey-glycerine mixture reduced by 25%. Separate lots were kept at 35° C. and 75% R. H., at 25° C. and 75% R. H., and at 35° C. and room humidity which at the time was about 20%. The average time from egg to adult was 57 days at 35° C. and 70 days at 25° C.

Determinations made on mature larvae are presented in Table VII. In the four cultures kept under three different sets of conditions the percentages of chitin in the cuticle were found to be approximately 36,

38, 39, and 40%. This is in good agreement with the value of 37.2% obtained from averaging the 50 samples from 30 larvae reared at 35° C. for the tests on reproducibility of determinations given in a previous section. While the 36% value calculates out to show a slight statistical significance, the fact that the 36% and 39% values were obtained from insects reared under similar conditions makes it doubtful that any significant difference can be attributed to either the temperature or humidity variable employed.

TABLE VII

CHITIN AND CUTICLE CONTENTS OF *Galleria* LARVAE REARED AT DIFFERENT TEMPERATURES AND HUMIDITIES

	Different Temperatures		Different Humidities	
	35° C. 75% R.H.	25° C. 75% R.H.	35° C. 75% R.H.	35° C. 20% R.H.
Number of samples	15	15	9	15
Average wet body wt.,[a] mg.	155.8	132.5	260.5	184.0
Dry weight of cuticle,[b] mg.	4.280	3.838	5.675	4.752
Dry weight of chitin,[c] mg.	1.561	1.460	2.156	1.898
Dry weight of chitin,[d] mg.	1.688	1.580	2.297	1.953
$\frac{\text{Chitin}^c}{\text{Dry cuticle}^b}$ %	36.1 ± 0.41	38.0 ± 0.72	38.9 ± 1.63	40.0 ± 1.29
$\frac{\text{Dry cuticle}^b}{\text{Dry body wt.}^e}$ %	7.52	7.86	5.96	7.07
$\frac{\text{Wet cuticle}^f}{\text{Wet body wt.}}$ %	4.04	4.26	3.20	3.80
$\frac{\text{Chitin}^d}{\text{Dry body wt.}}$ %	2.77	3.25	2.41	3.91
$\frac{\text{Chitin}^d}{\text{Wet body wt.}}$ %	1.09 ± 0.05	1.23 ± 0.05	0.89 ± 0.12	1.12 ± 0.04

[a]The larvae had an average water content of 63.4%.
[b]Cuticle of thorax and abdomen only: the water content was 32% when the cuticle was cleaned in liquid paraffin.
[c]Chitin purified from cuticle of thorax and abdomen only.
[d]Chitin purified from cuticle of thorax, abdomen and head.
[e]Dry body weight was calculated from wet body weight.
[f]Wet weight of cuticle was calculated from dry weight.

However, if instead of chitin/cuticle percentage, the chitin/body weight percentage is calculated, significant differences are found correlated to rearing conditions. In fig. 2, the percentages of chitin/dry cuticle, dry cuticle/wet body weight, and chitin/wet body weight are plotted against larval body weight. Considerable individual variation is shown but it can be seen that the percentages of dry cuticle and of chitin are negatively correlated to wet larval body weights although the

chitin content of dry cuticles remains constant.[3] Subsequent determinations on larvae ranging from 180 to 270 mg. showed that the water content of larvae varied from 58 to 69%, with no indication that larger larvae contained more water than smaller larvae. This suggests that the decrease in percentages of cuticle and chitin in fresh larvae is not an illusion due to a higher water content in the larger larvae. In other words, larger larvae of this species have relatively less cuticle. This is in marked contrast to the situation found in *Phormia* larvae and adult cockroaches.

Effects of Temperature and Diet on the Larval Cuticles of Phormia regina

Larvae were reared on normal, low carbohydrate and high carbohydrate diets consisting of casein (vitamin test brand), fine corn meal, dried brewer's yeast and powdered agar in proportions, respectively, of

TABLE VIII

CHITIN AND CUTICLE CONTENT OF *Phormia* LARVAE REARED ON DIFFERENT DIETS AT DIFFERENT TEMPERATURES

	35° C.			20° C.		
	Normal	Low Carbohydrate	High Carbohydrate	Normal	Low Carbohydrate	High Carbohydrate
Number of samples	30	30	30	30	30	30
Duration of immature stages, days	13	15	17	25	26	26
Average wet body weight,[a] mg.	51.5	51.3	44.1	38.8	37.7	39.1
Dry weight of cuticle,[b] mg.	1.532	1.398	1.203	1.167	0.972	1.154
Dry weight of chitin, mg.	0.711	0.651	0.598	0.605	0.468	0.585
$\frac{\text{Chitin}}{\text{Dry cuticle}}$ %	45.95	46.44	49.26	51.25	47.98	50.61
$\frac{\text{Dry cuticle}}{\text{Dry body wt.}^a}$ %	14.1	12.8	12.8	14.1	12.1	13.9
$\frac{\text{Wet cuticle}^b}{\text{Wet body wt.}}$ %	5.46	5.01	5.01	5.52	4.72	5.42
$\frac{\text{Chitin}}{\text{Dry body wt.}}$ %	6.48	5.96	6.62	7.33	5.80	7.02
$\frac{\text{Chitin}}{\text{Wet body wt.}}$ %[d]	1.39	1.29	1.35	1.51	1.24	1.50

[a]The larvae had an average water content of 78.7%. Dry body weight was calculated from wet weight.

[b]The water content of cuticle cleaned in liquid paraffin was 45.5%. Wet weight of cuticle was calculated from dry weight.

[c]S.E. d at 5% level = 1.43.

[d]S.E. d at 5% level = 0.15.

[3]In another moth, *Loxostege*, Pepper and Hastings (1943) found the lowest percentage of chitin ever reported for an insect cuticle, and, further, that the percentage almost doubles with age. However, the increase in chitin percentage is at least partly due to decrease in lipid content of the cuticle.

30 : 0 : 3 : 1, 20 : 10 : 3 : 1, and 10 : 20 : 3 : 1 by weight (each plus salts and sterilized. See Hill, Bell & Chadwick, 1946), and at temperatures of 20° and 35° C. Duration of the larval stages increased with decreasing temperature and with increasing amounts of corn meal in the diet. Generally but not always the larvae reared at the higher temperature were heavier.

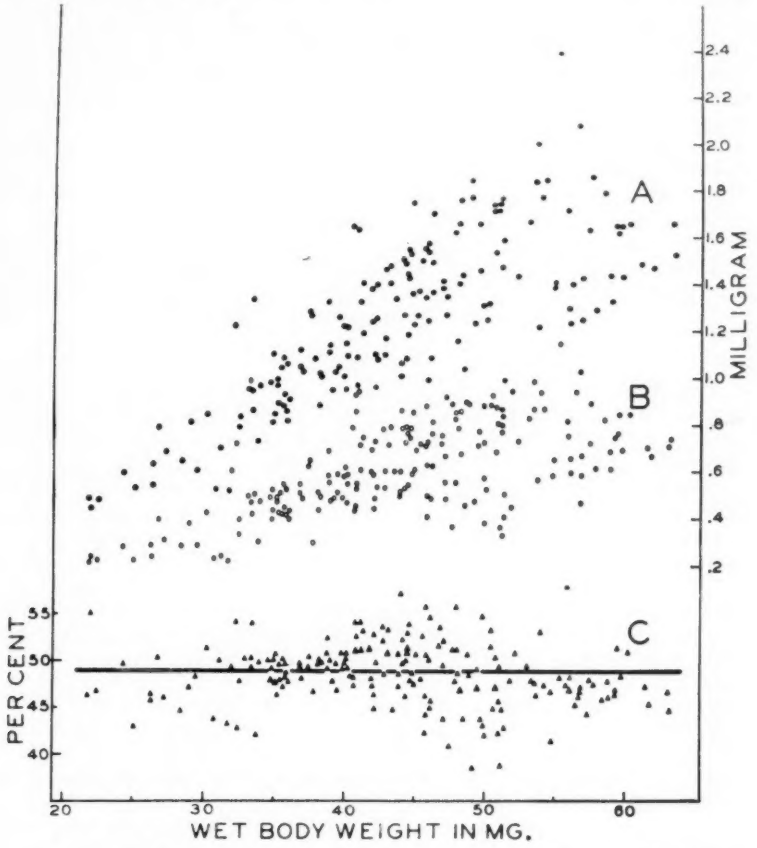


FIG. 3. Graphs for dry weight of chitin and cuticle in *Phormia regina* larvae as a function of size.
A. Dry weight of cuticle.
B. Dry weight of chitin.
C. Percentages of dry chitin to dry cuticle.

The data from the 180 larvae used are presented in Table VIII and graphically in fig. 3. The tabular results show that the percent of chitin in dry cuticles can be somewhat altered by diet in certain cases despite the fact that when all the values are graphed together the wide

scatter obliterates any visible grouping. Larvae reared on a high carbohydrate diet at 35° C. gave slightly but significantly higher values than those reared on the two other diets. Larvae reared on a low carbohydrate diet had the lowest percent of chitin in their cuticles of the groups reared at 20° C. Larvae grown on the same diet always gave slightly higher chitin values when the cultures were kept at 20° C. However, the differences are only a few percent.

The graphing of cuticle and chitin quantities and percentages as a function of wet body weight show a considerable scatter or considerable individual variation (fig. 3). The actual points plotted from groups *A* and *B* fit best to a slightly sigmoid curve (plotting the average value within each milligram group) but the scatter is so great that delineation of any specific line seems unwarranted. While the actual dry weights of cuticle and chitin increase with increasing larval size, the percentage values seem to remain constant. This seems to agree with the data reported by Dennell (1946) for *Sarcophaga* larvae.

The results also show that this species, like the beetle *Tribolium*, synthesizes chitin as well in the absence of free exogenous carbohydrate as in its presence. However, casein could be the source of the monosaccharide unit for chitin synthesis (Nilsson, 1936).

DISCUSSION

It is difficult to assess the validity of the majority of the published data on cuticle and chitin percentages. Most authors have simply stated a value with no indication of the number of determinations or number of individual insects involved. When the number has been recorded it has been clearly too small to establish the range of variability or a reproducible average. Nevertheless our data agree reasonably well with such published data as can be directly compared. A summary of our data is given in Table IX. Intraspecific or individual variation is not shown in this table but can be estimated from the scatter of points in figures 1–3. In *Galleria* larvae the average deviation from mean in cuticular chitin is 8%, in *Phormia* larvae it is 5%; the most extreme individual deviations are about 30% and 21% respectively.

No published data are available for *Blatta orientalis*. Comparison can, however, be made to data from other cockroaches. According to Tauber (1934), *Periplaneta fuliginosa* has about twice as high a percentage of chitin in relation to wet body weight and a considerably higher percentage (47%) of chitin in the abdominal cuticle (converting his chitosan value to chitin by dividing by the factor 0.79). In *Periplaneta americana* the chitin content of the cuticle has been variously stated as 38% (Koch, 1932), 35% for abdominal cuticles (Campbell, 1929) and 48.6% for abdominal tergites (Lafon, 1948); the lower two sets of values are similar to our determinations for *Blatta*.

Our determinations for one-day old adults of *Tenebrio molitor* are about the same as the value given by Lafon (1943c) for 60-day old beetles and much higher than his value (4.2%) for one-day old adults. No published values are available for comparison with our determinations on larvae or adults of *Tribolium confusum*.

For the larvae of *Galleria mellonella*, Lafon (1943b) has reported the chitin content of cuticles as 33.7%, and Niemierko & Cepelewicz (1950)

have reported the chitin content of dry larvae as 2–4%. Our values are somewhat higher than those of Lafon but similar to those of Niemierko & Cepelewicz.

For the larvae of *Phormia regina*, our results are somewhat lower than those given for *P. terranovae* by Fraenkel & Rudall (1947) who recorded 67.6% water in cuticles dissected in water, and 59.5% chitin in dry cuticles.

TABLE IX

SUMMARY OF AVERAGE PERCENTAGES OF WATER, CHITIN AND CUTICLE IN VARIOUS INSECTS REARED UNDER VARIOUS CONDITIONS

	Chitin	Water	Water	Dry cut.	Wet cut.	Chitin
	Dry cut.	Cuticle	Wet body	Dry body	Wet body	Dry body
Blatta						
adult, ♀			75.2	15.5*	5.0*	4.9
adult, ♂			72.7	13.8*	4.8*	4.9
abdominal						
tergite, ♀	31.7	12.0				
sternite, ♀	34.2	11.0				
tergite, ♂	35.0	9.2				
sternite, ♂	36.6	9.9				
Tribolium						
larva	22.8		44.5	11.7*		2.7*
adult			58.3			7.1
Tenebrio						
adult, ♀			65.8*			6.98
adult, ♂			66.5*			7.18
Galleria						
larva	38.3	32.0	63.4	7.1*	3.8*	3.0*
Phormia						
larva	48.6	45.5	78.7	13.3*	5.2*	6.5*

*Values are estimated by calculations from measurements of portions of the animal or from different lots of animals. Other values are averages of percentages calculated from measured values only.

Temperature has a considerable effect on rate of growth and eventual size of the individual but it has little or no direct effect on the cuticular percentages: in *Galleria* larvae there appears to be no appreciable effect (Table 7); in *Phormia* larvae the possible effect in only of the order of 5% (Table 8). Cuticular and chitin percentages do vary as a function of size in *Galleria* larvae (fig. 2), as has also been recorded for *Tenebrio* larvae by Lafon (1943c), but not in *Phormia* larvae (fig. 3) or *Blatta* adults (fig. 1). The decrease in percentage of cuticle with increasing size of larva in *Galleria* correlates closely with decreasing surface area (Bounoure, 1913): the largest larvae have about twice as much cuticle as the smallest larvae, this being some 30–40% less in relation to body weight. In *Phormia* and *Blatta*, however, close agreement is not obtained by correcting for surface area; in these species the cuticle increases in close proportionality to increasing body weight. A number of authors (*e.g.* Klinger, 1936; Millot & Fontaine, 1938), have reported increases in thickness of the cuticle with age or size but such data are not comparable to our values.

Similarly, unfavorable diets affect growth rate and size but have no

detectable effect on the cuticles of *Blatta* and *Tenebrio*, and only slight effects of questionable biological significance on the cuticles of *Tribolium* and *Phormia*. Of most interest in connection with the effects of diets are the facts that the chitin and cuticle percentages in larvae of *Tribolium* show little or no difference correlated with the presence or absence of glucose, the chitin content of adults of *Tribolium* show only a small albeit statistically significant difference, and the chitin and cuticular percentages of larvae of *Phormia* are of uncertain significance because the lowest values were obtained from a diet containing some carbohydrate. At least for non-sterile conditions, it must be concluded that insects such as *Tribolium* and *Phormia*, which grow readily in the absence of free exogenous carbohydrate synthesize chitin (and cuticle) about equally well in the presence or absence of free carbohydrate. The casein used, however, may supply adequate glucosamine for synthesis of this chitin (Nilsson, 1936).

Differences in amount of cuticle related to quantity of food consumed have been reported for *Rhodnius*, an intermittent feeder (Wigglesworth, 1942), and for *Bombyx* larvae (Kuwana, 1933). The five species of insects used in the present study are all constant feeders which were allowed to feed at will on an excess of the designated diet. Accordingly the negative or nearly negative results of diet in the present study are related to *composition* of the diet and cannot validly be compared to variations correlated with *quantity* of food consumed.

SUMMARY

1. The effects of diet, age, temperature and humidity on the percentages of cuticle and of chitin in cuticles are presented for the oriental cockroach, *Blatta orientalis* L., the confused flour beetle, *Tribolium confusum* Duv., the yellow mealworm, *Tenebrio molitor* L., the wax moth, *Galleria mellonella* (L.) and a blowfly, *Phormia regina* (Mg.).

2. The experimental deviations for chitin or chitosan estimates in cuticles of wax moth larvae, as determined from identical samples, are less than 3%. No estimate is available for the true experimental error in the values determined.

3. Low temperatures retard the growth rate of the wax moth and the blowfly. Low carbohydrate diets also retard the growth rate of either cockroaches or mealworms, while a high carbohydrate content in the diet prolongs the immature stages of the blowfly. However, neither temperatures nor diets definitely affect the cuticle values when these are expressed in percentage terms. Insects were allowed to feed at will, and dietary control was only of composition; accordingly, these data cannot be compared with reports dealing with variations correlated with quantity of food consumed.

4. The chitin content of abdominal cuticles of male oriental cockroaches is higher than that of females; and the chitin content of abdominal tergites is lower than that of sternites.

5. In wax moth larvae the percentages of chitin or cuticle decrease with increasing body weight (fig. 2). In blowfly larvae and cockroach adults the percentage of chitin or cuticle in relation to body weight remains constant (figs. 1 & 3).

6. Individual variation of chitin content of dry cuticles within similar stages of a single species shows an average deviation of approximately 8% in wax moth larvae (fig. 2) and 5% in blowfly larvae (fig. 3); with the most extreme individuals deviating about 30% and 21% respectively. There is also a similar degree of individual variation in total chitin or cuticle content of these two species.

7. Variation positively correlated with and so presumably directly due to any of the experimental treatments employed is either absent or of the order of only a few percent.

LITERATURE CITED

Bounoure, L. 1913. L'influence de la taille des insectes sur le production de la chitine, sécrétion de surface. C. R. Acad. Sci., 157: 140–142.

Campbell, F. L. 1929. The detection and estimation of insect chitin. Ann. Ent. Soc. Amer., 22: 401–426.

Dennell, R. 1946. A study of an insect cuticle: the larval cuticle of *Sarcophaga falculata* Pand. (Diptera). Proc. Roy. Soc. London, (B), 133: 348–373.

Fraenkel, G., and **K. M. Rudall.** 1947. The structure of insect cuticles. Proc. Roy. Soc. London, (B), 134: 111–143.

Haydak, M. H. 1943. A basic diet. *In* Laboratory Procedures in Studies of the Chemical Control of Insects. Amer. Assoc. Adv. Sci., Publ. No. 20, p. 56.

Hill, D. L., V. A. Bell and **L. E. Chadwick.** 1947. Rearing of the blowfly, *Phormia regina* Meigen, on a sterile synthetic medium. Ann. Ent. Soc. Amer., 40: 213–216.

Klinger, H. 1936. Die Insectizidewirkung von Pyrethrum und Derrisgiften und ihre Abhängigkeit vom insecten Korper. Arb. Physiol. angew. Ent., 3: 49–69, 115–151.

Koch, C. 1932. Der Nachweis des Chitins in tierischen Skeletsubstanzen. Z. Morph. Ökol. Tiere, 25: 730–756.

Kuwana, Z. 1933. Notes on the growth of cuticle in the silkworm. Proc. Imp. Acad. Tokyo, 9: 280–283.

Lafon, M. 1943a. Sur la structure et la composition chimique du tégument de la Limule (*Xiphosura polyphemus* L.). Bull. l'inst. Oceanogr., No. 850, 11 pp.

1943b. Recherches biochemiques et physiologiques sur le squelette tégumentaire des arthropodes. Ann. Sci. Nat., ser. Bot. Zool., 11: 113–146.

1943c. Recherches sur le cycle de la chitine chez quelque coléoptères. Arch. Zool. Exp. + Gen., 83: 58–70.

1948. Nouvelles recherches biochimiques et physiologiques sur le squelette tégumentaire des crustacés. Bull. l'Inst. Oceanogr., No. 939, 28 pp.

McCay, C. M., and **R. H. Melampy.** 1937. Care and rearing of *Blatella germanica*. *In* Culture Methods for Invertebrate Animals. Comstock Publ. Co., Ithaca, N. Y., p. 283.

Millot, J., and **M. Fontaine.**, 1938. Le taux de chitine chez *Schistocerca gregaria*. Bull. Soc. Zool., 63: 123–124.

Niemierko, W., and **S. Cepelewicz.** 1950. Studies in the biochemistry of the waxmoth (*Galleria mellonella*). 1. Growth of the larvae and their chemical composition. Acta Biol. Exp. (Poland), 15: 57–68.

Nilsson, J. 1936. Zur Bestimmung von Glucosamin in Proteinstoffen. Biochem. Zts., 285: 386–389.

Pepper, J. H., and **E. Hastings.** 1943. Age variations in exoskeletal composition of the sugar beet webworm and their possible effect on membrane permeability. J. Econ. Ent., 36: 633.

Richards, A. G. 1949. Studies on arthropod cuticle. 3. The chitin of *Limulus*. Science, 109: 591–592.

1951. The Integument of Arthropods. University of Minnesota Press, Minneapolis, Minn.

Tauber, O. E. 1934. The distribution of chitin in an insect. J. Morph., 56: 51–58.

Wigglesworth, V. B. 1942. Some notes on the integument of insects in relation to the entry of contact insecticides. Bull. Ent. Res., 33: 205–218.

EUHAEMOGAMASUS KEEGANI, NEW SPECIES, A PARASITIC MITE FROM WESTERN NORTH AMERICA

(Acarina: Laelaptidae, Haemogamasinae)

E. W. JAMESON, JR.
Department of Zoology, University of California, Davis

In the western United States there are two closely related species of *Euhaemogamasus* Ewing both of which can be keyed to *Euhaemogamasus liponyssoides* (Ewing) in the recent paper by Keegan (1951: 227). One of these Keegan described as a new subspecies, *E. l. occidentalis*, but the other species is unnamed. Three females and one nymph of the second species were believed by Keegan (p. 257) to be intermediate between the two subspecies of *liponyssoides*. Although the two species are very similar, there are several constant features by which they can be distinguished, and these characters are not intermediate between the two forms of *liponyssoides*. Inasmuch as both *liponyssoides* and the species named below may occur in the same localities, they cannot be regarded as subspecies. The following comments about *liponyssoides* pertain to specimens collected in Plumas County, California; these individuals represent *E. l. liponyssoides*.

Euhaemogamasus keegani, new species

Female.—*Venter* (fig. 1, E): Sternal plate (fig. 2, E) with three pairs of setae, all smooth, unbarbed; sternal plate almost twice as broad as long at the narrowest points, irregularly concave caudally, reaching forward to a point about on a line connecting the bases of the third pair of sternal setae; caudo-lateral extensions of sternal plate of *keegani* in contrast to the angular or rounded corners in *liponyssoides* (fig. 2, F). Genito-ventral plate rather narrow for the genus, with an irregular outline; 11 to 15 setae on genito-ventral plate. Anal plate as in *liponyssoides*, with the usual paired adanal setae, a single postanal seta, and seven accessory setae. The peritreme (fig. 2, A) is distinctive in that the tubular part is conspicuously shorter than in *liponyssoides* (fig. 2, B).

Gnathosoma (fig. 1, D): Similar to both subspecies of *liponyssoides*. Mesal seta of palpal segment I inflated, hyaline. Hypostomal teeth in ten or eleven rows of one to four teeth each. Chelicera (fig. 1, B) of a characteristic shape, untoothed and hyaline throughout; fixed arm with a minute pilus dentilis, moveable arm with a lateral hump; no setae subtending moveable arm.

Male.—*Venter* (fig. 1, A): In general quite similar to *liponyssoides*. The peritreme is short, as in the female, and serves to distinguish *keegani* from *liponyssoides*. The holoventral plate is concave laterally behind coxae IV; in *liponyssoides* it is slightly convex. The stout

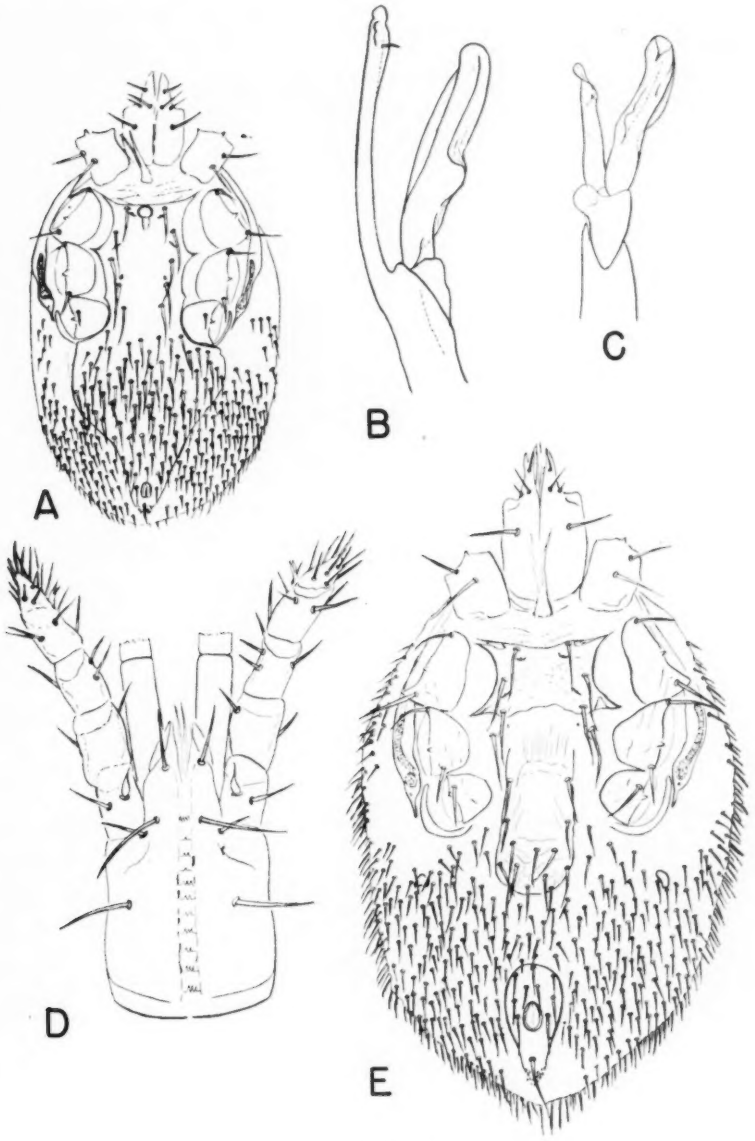


FIGURE I

ventral seta on femur II is considerably thicker and tapers more abruptly (fig. 2, C) in contrast to the less modified shape in *liponyssoides* (fig. 2, D).

Gnathosoma: Same as female. Chelicera (fig. 1, C) untoothed and hyaline; moveable arm terminates in an acute hook; fixed arm with a minute pilus dentilis. The juncture is covered ventrally by a hyaline shield; no subtending row of setae or fine hairs at bases of arms.

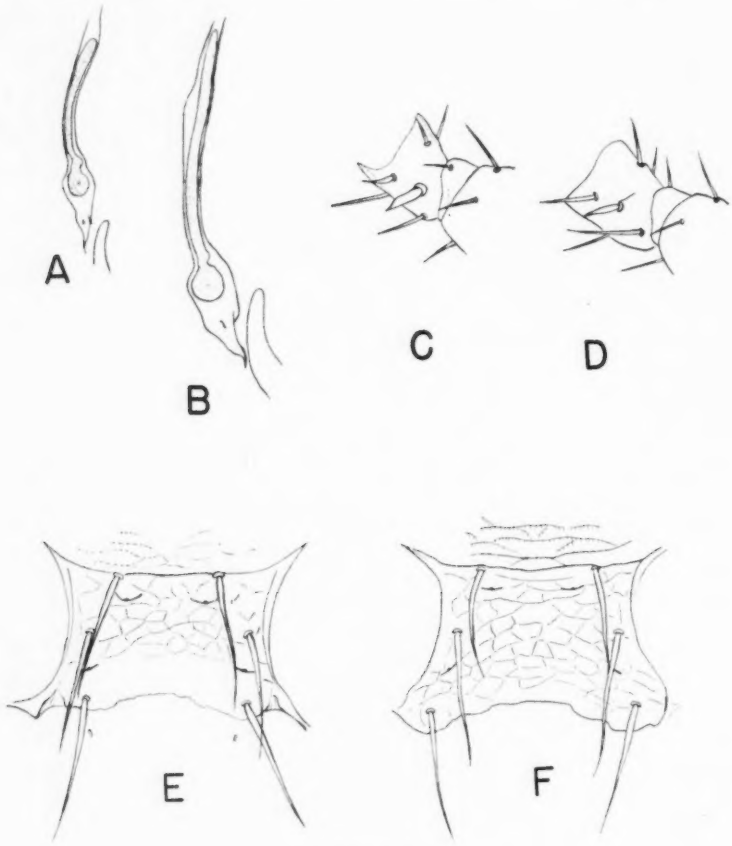


FIGURE 2

Type host: Sorex trowbridgii Baird, long-tailed shrew.

Type locality: Quincy, Plumas County, California.

Types: Holotype female, 19 July 1951; *allotype* male, 29 September 1949; deposited with the United States National Museum. *Paratypes:* All from type locality. From *Sorex trowbridgii:* one male, 12 April

1949; one male, 27 April 1949; one male, 16 August 1949; one male, 8 September 1949; one male, 13 October 1949; one female and two males, 8 October 1950; one female, 30 November 1950; one female, 6 December 1950; one female, 18 July 1951; one male, 19 July 1951. From the shrew-mole, *Neurotrichus gibbsi* (Baird); one male, 24 October 1948; one male, 29 April 1949; one male, 17 August 1949; one male and two females, 18 August 1949; one female, 3 August 1950; one male, 20 July 1951.

One additional specimen, not designated as a paratype, is from a deer mouse, *Peromyscus melanotus* J. A. Allen and Chapman, Mexico, Districto Federal, 8.4 miles east of Amecameca, 21 July, 1950; collected by Paul S. Martin. Also, undoubtedly of this species, are the three females and one nymph mentioned by Keegan (1951: 257); these specimens are from a mole, *Scapanus townsendi* (Bachman) from Lake County, Oregon. I have not seen these specimens, but Keegan has illustrated them (p. 254) and they are most certainly *E. keegani*.

Remarks:—The slender, hyaline, untoothed chelicerae and the unbarbed setae of *liponyssoides* and *keegani* separate them from all other described species of *Euhaemogamasus*. These two species are very similar, and resemble a species in the genus *Haemogamasus*, *H. harperi* Keegan, a parasite of insectivores in the southeastern United States. Although the accessory sternal setae of *Haemogamasus* provide a simple means of distinguishing *harperi* from *liponyssoides* and *keegani*, it is interesting to compare the three species.

In the length-width ratios of tarsi, *keegani* is intermediate between *liponyssoides* and *harperi*, but seems closer to the latter (Table I).

TABLE I

LENGTH-WIDTH RATIOS OF TARSI OF *Euhaemogamasus liponyssoides* (EWING), *E. keegani*, NEW SPECIES, AND *Haemogamasus harperi* KEEGEN

SPECIES	TARSUS			
	I	II	III	IV
E. liponyssoides	4.8 : 1	4.2 : 1	6 : 1	8 : 1
E. keegani	4 : 1	4 : 1	5 : 1	6 : 1
H. harperi	4 : 1	3.5 : 1	4.5 : 1	5 : 1

The species *keegani* and *liponyssoides* differ appreciably in the number of genito-ventral setae (Table II). In this feature *keegani* is closer to *harperi*, the latter possessing from 11 to 18 genito-ventral setae in 18 specimens examined by Keegan (1951: 223).

TABLE II

GENITO-VENTRAL SETAE OF *Euhaemogamasus keegani*, NEW SPECIES, AND *E. liponyssoides* (EWING)

	E. keegani					*E. liponyssoides*						
Number of setae	11	12	13	14	15	26	27	28	29	30	31	32
Frequency	1	1	1	5	3	1	0	1	1	4	2	1

It seems a little contradictory that the species *E. keegani* more nearly resembles a species in a different genus, *H. harperi*, than other members of *Euhaemogamasus*. Although the two genera are useful categories, apparently they are not natural groups. The accessory sternal setae of *harperi* vary from four to seven (Keegan, 1951: 223). Eventually we may find individuals of this species with no accessory sternal setae at all, but this awkward situation has not yet been encountered.

I wish to thank Dr. E. W. Baker for the loan of specimens of *Euhaemogamasus liponyssoides occidentalis* Keegan and *Haemogamasus harperi* Keegan from the United States National Museum collection. This new species is named for Captain Hugh L. Keegan, U. S. Army, in recognition of his excellent study of the Haemogamasinae.

LITERATURE CITED

Keegan, Hugh L. 1951. The mites of the subfamily Haemogamasinae (Acari: Laelaptidae). Proc. U. S. Nat. Mus., 101: 203–268.

A BRIEF HISTORY OF ENTOMOLOGY, by HERBERT OSBORN. iii+303 pp., 58 plates of portraits. Spahr and Glenn Co., Columbus, Ohio. 1952. Price, $4.50.

It is remarkable for a man closely approaching the century mark to have the vitality and youthfulness still to write a full-length book on a technical subject. Dr. Osborn's interests have long been directed into the field of entomological history, much of which has been made during his long life-time. He was a small boy when Darwin wrote his "Origin of Species" and when Mendel published his epoch making paper on the genetics of peas; as a young man he was contemporaneous with the aging Charles Darwin, Townsend Glover, Francis Walker, and Asa Fitch. His "Fragments of Entomological History" should be well known to every entomologist. It is from this background that the present work has been written.

Much more condensed and much less anecdotal than the *Fragments*, this work attempts to trace entomological history from prehistoric times to the present day. It is divided into three parts. The first sketches the development of entomology in commerce, agriculture, sericulture, insect control, classification, anatomy and physiology, and parasitology; also the history of entomological societies, periodicals, and congresses, and the teaching of entomology. The second part deals with regional entomology in various parts of the world. The third is devoted to brief personal sketches of the makers of entomological history. The plates consist of 522 photographs. (Regretably, the author's modesty did not permit him to include his own.)

One might regret that the Dean of American Entomology did not have, to supplement his great fund of information, a younger coworker to treat more adequately the newer aspects of entomology and to correct the many typographical errors, miscitations and unfilled blanks that occur in the book.—M. T. J.

A STUDY OF FLIGHT RANGE AND LONGEVITY OF BLACKFLIES (DIPTERA, SIMULIIDAE) INFECTED WITH ONCHOCERCA VOLVULUS[1]

HERBERT T. DALMAT AND COLVIN L. GIBSON

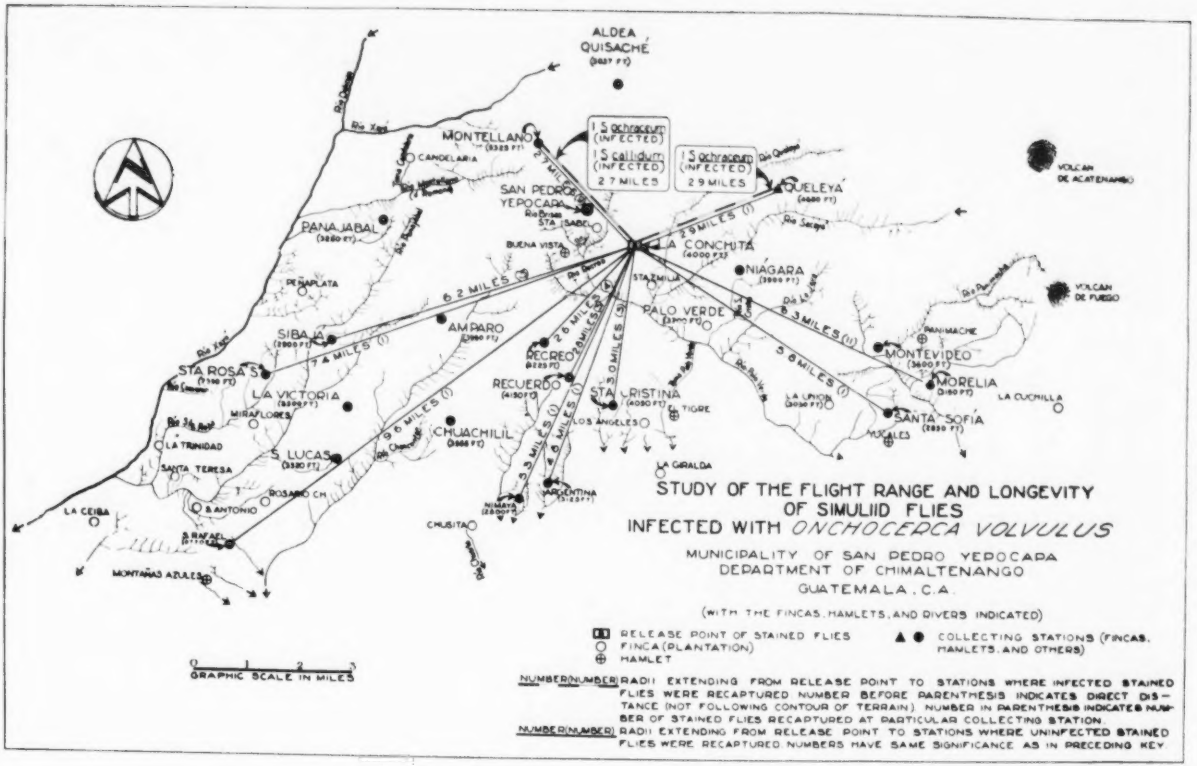
In 1949 and 1950 studies were made of the flight range and longevity of the principal anthropophilic species of Simuliidae in the region of San Pedro Yepocapa, Guatemala (1, 2). Since it was determined in these studies that the adult females could traverse distances as great as 9.7 miles, measured as a straight line on the map, and that they could live at least 85 days, considering only the time from marking to recapture, it was decided to repeat the experiments using flies that had been permitted to feed on persons known to be infected with onchocerciasis and known to be infective to the flies. It was hoped that this study would help explain the restricted distribution of the disease in Guatemala by showing the effect of infection on the flight range and longevity of the flies. Such information would also be useful in formulating effective anti-*Similium* measures for the control of human onchocerciasis.

The area chosen for this study consists of approximately fifty square miles in the municipality of San Pedro Yepocapa, Department of Chimaltenango, Guatemala, site of the previous investigations. It is situated on the western slope of the volcanoes Acatenango and Fuego, the altitude varying from 2,000 to 5,500 feet (see map). This area was selected because of its accessibility from the field laboratory, and because it is a region in which *Simulium ochraceum*, *S. metallicum*, and *S. callidum*, the principal anthropophilic species in Guatemala, can normally be collected in great abundance. The field experiments lasted 83 days, from December 8, 1950, through February 28, 1951. During this period 5.6 inches of rain were recorded; the average daily maximum temperature was 77.5° F. and the average daily minimum was 57.2° F., with an absolute maximum and minimum of 84.2° F. and 51.8° F.; the average relative humidity was 75.2 with maximum and minimum of 100 and 46.5; the winds were minimal and the skies were generally clear with cumulus clouds.

MATERIALS AND METHODS

Because of the ease with which aniline dyes can be used as markers, and because of the excellent results they yielded in previous experiments (1, 2), these dyes were again employed in the present study.

[1]From the National Microbiological Institute of the National Institutes of Health, U. S. Public Health Service, Federal Security Agency. This report is part of a study jointly supported by the Laboratory of Tropical Diseases of the National Microbiological Institute and the Pan American Sanitary Bureau in cooperation with the Dirección General de Sanidad Pública of the Republic of Guatemala. The project was aided by a research grant from the National Institutes of Health, Bethesda, Maryland.


ALDEA QUISACHÉ (3627 FT)
MONTELLANO (3320 FT)
1 S ochraceum (INFECTED)
1 S callidum (INFECTED)
2.7 MILES
1 S ochraceum (INFECTED)
2.9 MILES
QUELEYÁ (4600 FT)
VOLCAN DE ACATENANGO
SAN PEDRO YEPOCAPA
PANAJABAL (3280 FT)
LA CONCHITA (4000 FT)
NIAGARA (3900 FT)
VOLCAN DE FUEGO
PALO VERDE (3900 FT)
SIBAJ (3900 FT)
AMPARO (3980 FT)
DECREO (4225 FT)
RECUERDO (4150 FT)
STA. CRISTINA (4050 FT)
MONTEVIDEO (3600 FT)
MORELIA (3160 FT)
STA. ROSA (1100 FT)
LA VICTORIA (3200 FT)
S. LUCAS (3320 FT)
CHUACHILIL (3980 FT)
SANTA SOFÍA (2880 FT)
LA CUCHILLA
LA CEIBA
MONTAÑAS AZULES
CHUSITA
ARGENTINA (3123 FT)
LA GIRALDA
STUDY OF THE FLIGHT RANGE AND LONGEVITY OF SIMULIID FLIES INFECTED WITH *ONCHOCERCA VOLVULUS*
MUNICIPALITY OF SAN PEDRO YEPOCAPA
DEPARTMENT OF CHIMALTENANGO
GUATEMALA, C.A.
(WITH THE FINCAS, HAMLETS, AND RIVERS INDICATED)
RELEASE POINT OF STAINED FLIES
FINCA (PLANTATION)
HAMLET
COLLECTING STATIONS (FINCAS, HAMLETS, AND OTHERS)
GRAPHIC SCALE IN MILES
NUMBER/NUMBER RADII EXTENDING FROM RELEASE POINT TO STATIONS WHERE INFECTED STAINED FLIES WERE RECAPTURED. NUMBER BEFORE PARENTHESIS INDICATES DIRECT DISTANCE (NOT FOLLOWING CONTOUR OF TERRAIN). NUMBER IN PARENTHESIS INDICATES NUMBER OF STAINED FLIES RECAPTURED AT PARTICULAR COLLECTING STATION.
NUMBER(NUMBER) RADII EXTENDING FROM RELEASE POINT TO STATIONS WHERE UNINFECTED STAINED FLIES WERE RECAPTURED. NUMBERS HAVE SAME SIGNIFICANCE AS IN PRECEDING KEY.

Six dyes (Victoria green, methylene blue chloride, Bismarck brown, acid fuchsin, safranin O, and safranin bluish) were chosen for their ability to impart distinctive colors to the solvent used for detecting the dyes on captured flies. This solvent consisted of a mixture of absolute ethyl alcohol, glycerine, and chloroform in the proportion of 3 : 2 : 1. Each marker was prepared by grinding one part of dye with nine parts of refined flour in a mortar for one-half hour.

Each of the six dyes was used on two consecutive days, resulting in a total of only 12 days on which flies were stained. This procedure made possible the tracing of recaptured flies with an error no greater than one day. On each of these 12 days, flies were collected and stained from 8:00 a.m. to 11:30 a.m. and from 2:00 p.m. to 5:00 p.m. Eighteen collectors captured flies while they were biting six subjects who previously had been shown to have heavy infections of microfilariae of *Onchocerca volvulus* and who had demonstrated their ability to infect wild flies (see below). Collections were made by placing the mouth of a 23 ml. test-tube over flies that had fed until only about half-engorged. When the tubes contained approximately forty flies, the number of each of the three species was noted, and the dye-flour mixture was then blown into the tube by means of a rubber bulb-syringe. This dust was permitted to settle one minute, after which the flies were released. Care was taken not to hold the flies more than 15 minutes from the time of original capture until release.

In order to secure adequate human subjects for infecting the flies, two criteria were adopted: (1) the individual had to show active microfilariae in at least two of four cutaneous biopsies; and (2) flies which were fed on the individual had to ingest microfilariae of *Onchocerca volvulus* and support normal development of the parasite for at least 72 hours under laboratory conditions. It was necessary further to limit the selection to male patients of sufficient age that they could remain away from their homes for the duration of the staining phase of the program. Since this study was carried on during the annual coffee harvest, it was difficult to examine large groups of infected plantation workers from whom the necessary subjects could be chosen. In all, 213 individuals were examined by skin biopsy technique, of whom only 16 satisfied the first criterion of two positive biopsies among the four which were taken. These 16 individuals were then tested for their ability to infect flies by allowing approximately a hundred simuliids to feed on each person. The flies were then maintained in the laboratory in Gebert tubes, with moistened raisins for food, according to our modification (3) of the technique recommended by Wanson, Henrard, and Peel for the experimental study of the developmental cycle of *Onchocerca volvulus* in its insect host (4). Flies which died before the third day were discarded; those which lived three days or more were observed frequently, and were dissected immediately after they died to determine if they had become infected.

On the basis of these dissections, the six individuals who produced the highest proportion of infected flies were chosen as subjects for the flight range and longevity experiment. It is interesting to note that only one-quarter of the flies which fed on these six subjects survived three days or more; of these, approximately 24 percent showed develop-

ing filarid larvae when dissected. These rates of survival and infection agreed closely with those previously obtained in more extensive experimental infection studies (3) and indicated that the six individuals chosen as subjects for the present study were capable of establishing normal infections in simuliid flies.

In order to re-collect stained flies, 21 collecting stations were established in all directions from the release point, and at varying distances from it (see map). Since it was desired to determine how long infected adults can live in nature, as well as how far they are able to fly in comparison with noninfected flies, it was decided to postpone the

TABLE I

COLLECTING STATIONS

Finca	Distance From Release Point (Miles)*	Number of Times Visited	Finca	Distance From Release Point (Miles)*	Number of Times Visited
Amparo	3.8	25	Quisaché	3.0	2
Argentina	4.8	51	Recreo	2.6	40
Chuachilil	4.9	3	Recuerdo	2.8	39
Conchita	0.0	20	Sta. Christina	3.0	37
Montellano	2.7	48	San Lucas	7.1	32
Montevideo	5.1	55	San Rafaël	9.6	30
Morelia	6.3	55	Sta. Rosa	7.4	54
Niágara	2.1	1	Sta. Sofía	5.8	52
Nimayá	5.3	51	Sibaja	6.2	54
Panajabal	4.8	5	Victoria	6.3	1
Queleyá	2.9	14			
TOTAL NUMBER OF COLLECTIONS MADE					669

*Straight-line map distance.

recapture of stained flies until several days after staining was begun. Had captures been initiated concurrently with release of the flies, the population of stained flies probably would have been unnecessarily reduced. For this reason, captures of flies at the collecting stations were not begun until the ninth day of staining. Thereafter, a total of 669 visits was made to the 21 stations on 60 nonconsecutive days (Table I). These collections were made by 18 collectors working in pairs, each collecting flies from the other. No attempt was made to allow the flies to feed. Collected flies were returned to the laboratory as rapidly as possible, so that they might be examined the same day as collected and while still alive. The flies were passed, one at a time, into the alcohol-glycerine-chloroform solvent in a watch glass on the stage of a dissecting microscope. Stained flies, upon contact with the liquid, imparted to it the characteristic color of the dye. The flies so examined and recognized as having been previously stained were then identified as to species, and fixed in Duboscq-Brasil solution. They were subsequently embedded, serially-sectioned in the sagittal plane, and stained with Delafield's hematoxylin, after which they were

examined microscopically to determine if they were infected and the degree of development reached by the ingested filarid larvae.

RESULTS AND DISCUSSION

A total of 40,474 simuliid flies, which had fed on onchocercotic patients, was released after being marked with aniline dyes by the technique described above. Of this number, 30,748 were ***Simulium ochraceum***, 8,625 were *S.* ***metallicum***, and 1,101 were *S.* ***callidum***. Subsequent to the release of these stained flies, a total of 144,708 simuliids was captured at the 21 collecting stations, of which 55,366 were *S.* ***ochraceum***, 81,475 were *S.* ***metallicum***, and 7,867 were *S.* ***callidum***. Among these were 42 flies which had been stained by one of the aniline dye markers.

Sectioning of these 42 marked flies revealed only three infections. One ***Simulium ochraceum***, which had flown 2.9 miles from the release point in two or three days, contained about twenty microfilariae in the abdominal blood mass and one in the thoracic muscles. The latter larva, which measured 240 μ by 4.2 μ, stained precisely and

TABLE II

RECORD OF FLIES STAINED AT RELEASE POINT
(December 8–9 and 11–20, 1950)

	ochraceum	*metallicum*	*callidum*	TOTAL
Number of Flies Stained and Released	30,748	8,625	1,101	40,474

appeared to be completely normal, while the microfilariae in the abdominal blood mass appeared to be degenerating, as evidenced by poorly defined staining. The two other infected flies, which had flown 2.7 miles from the release point in three or four days, harbored "sausage" forms in the thoracic muscles. One of these flies, *S.* ***ochraceum***, contained one filarid larva; the other, *S.* ***callidum***, contained two larvae. Only one of the three larvae could be accurately measured in the sectioned material. This specimen, which was 184 μ long by 21 μ wide, was very precisely stained and showed the internal anatomy quite clearly.

The three flies just described most likely became infected on the day they were marked and released, since the filarid developmental forms in each agreed closely with stages found after corresponding intervals of time in laboratory infections (3). Although only a small number of infected flies was recovered, it can be concluded that infected blackflies can, and do, travel some distance from the point of infection. Therefore, measures for the control of infected ***Simulium*** might have to be extended at least 2.9 miles beyond the area to be protected in any program for the control of human onchocerciasis in Guatemala.

It is interesting to note that not one infected fly was recovered which had survived more than four days after being stained. This fact, coupled with the small number of infected flies that was recovered,

makes it difficult to draw definite conclusions about the longevity of infected flies under natural conditions. From past experience with numerous infection experiments (3), it is known that approximately one-half of the flies which take blood from a heavily infected person ingest microfilariae and subsequently become infected. On this basis it can be presumed that approximately one-half of the 40,474 flies that were fed, stained, and released in the present study became infected. If no mortality occurred, it would therefore be expected that infections

TABLE III

RECORD OF FLIES CAPTURED AT COLLECTING STATIONS
(December 18, 1950 to February 28, 1951)

COLLECTING PERIOD*	TOTAL NUMBER OF FLIES CAPTURED (Stained and Unstained)			NUMBER OF STAINED FLIES RECOVERED			COLLECTING STATION	DISTANCE (Miles)
	ochraceum	*metallicum*	*callidum*	*ochraceum*	*metallicum*	*callidum*		
Dec. 18–27	3,095	5,563	1,169	2	7	....	Morelia	6.3
				5	4	2	Montellano	2.7
				1	1	....	Quelayá	2.9
				2	2	....	Recreo	2.6
				1	....	....	Sta. Sofía	5.8
				1	2	....	Sibajá	6.2
				....	1	....	Sta. Cristina	3.0
				....	1	....	Recuerdo	2.8
Dec. 28–Jan. 5	7,325	11,707	1,790	1	....	....	Argentina	4.8
				....	2	....	Recuerdo	2.8
				....	1	....	Sta. Cristina	3.0
				....	....	1	Sta. Rosa	7.4
Jan. 6–13	11,261	12,514	871	....	....	....	....	....
Jan. 15–22	8,713	11,240	860	....	....	....	....	....
Jan. 23–31	6,380	11,513	750	....	....	....	....	....
Feb. 1–8	4,959	8,921	718	1	1	....	Morelia	6.3
				....	1	....	San Rafaél	9.6
Feb. 9–16	4,968	8,789	742	1	....	....	Sta. Cristina	3.0
				....	....	1	Nimayá	5.3
Feb. 17–24	5,960	8,157	867	....	....	....	....	....
Feb. 26–28	2,705	3,071	160	....	....	....	....	....
TOTALS	55,366	81,475	7,867	15	23	4		
GRAND TOTALS	144,708			42				

*Collections were made on only seven days of each period except the last, which comprises only three collecting days.

should be found in one-half of the 42 flies which were recovered. Since only three infected flies were recovered, the possibility is suggested that infection with *Onchocerca volvulus* may have a deleterious effect upon the flies and thereby cause the early death of many of them. It has been repeatedly observed in the laboratory that simuliids infected with *O. volvulus* larvae show a high mortality rate during the first four days after the infective meal; furthermore, they die more rapidly than uninfected flies under laboratory conditions (3). Thus, because so few infected flies were recovered in the present experiment, none of which had survived more than four days after infection, the possibility is suggested that the high post-infection mortality observed in the laboratory also occurs in the field.

TABLE IV

LONGEVITY DATA

Days elapsed from staining to recapture	NUMBER OF FLIES		
	Simulium ochraceum	*Simulium metallicum*	*Simulium callidum*
2	4	8	..
3	1*	1	..
4	2*	3	2*
6	1	2	..
8	2	1	..
9	1	..	..
10	1	1	..
12	..	1	..
14	..	1	..
15	1	2	1
45	..	1	..
54	1	2	..
55	..	..	..
62	1	..	..
63	..	..	1

*Each starred item includes one infected fly.

Approximately fifteen days are required after infection for the development of infective larvae in the species of *Simulium* used in the present studies.[2] Therefore, it perhaps is possible that the last six flies listed in Table IV, which were collected 45 days or more after staining, might have become infected during the experiment and subsequently have lost their infection before they were recaptured. Such "lost" infection would probably have been recognized by pathological alterations of the thoracic muscles or the presence of shed cuticular remnants in the sectioned flies. Even if such infections had not been recognized, the addition of these six possible infections to the three already known would give a total far below the number

[2]Gibson, Colvin L., unpublished data

expected if no mortality of flies occurred because of their parasite burden.

REFERENCES

1. **Dalmat, Herbert T.** 1950. Studies on the flight range of certain Simuliidae with the use of aniline dye marker. Ann. Ent. Soc. Amer., 43(4): 537–545.
2. 1952. Longevity and further flight range studies on the blackflies (Diptera, Simuliidae), with the use of dye markers. Ann. Ent. Soc. Amer. 45(1): 23–37.
3. **Gibson, Colvin L.** 1951. Parasitological studies on onchocerciasis in Guatemala. (Doctoral Dissertation.) University of Michigan, Ann Arbor.
4. **Wanson, M., Henrad, C.,** and **Peel, E.** 1946. *Onchocerca volvulus* Leuckart. Indices d'infection des simulies agressives pour l'homme. Cycle de developpement chez *Simulium damnosum* Theobald. Recueil Travaux Sci. Med. au Conge Belge, 4: 122–138.

THE DESIGN AND ANALYSIS OF EXPERIMENTS, by OSCAR KEMPTHORNE. Pp. xix+631. New York: Wiley; London: Chapman and Hall, 1952. $8.50.

This book, with excellent print and physical make-up, is stated by its editor to complement rather than to rival Cochran and Cox's "Experimental Designs." It gives more attention to mathematical foundations, and less to cataloging of practical designs with specific instructions for their use. The contributions of such workers as Wald, Cramer and Neyman are considered along with those of the Fisher school. The book will probably be most useful as a reference work for biometricians, and for experimenters who are rather advanced mathematically.

Two excellent and much needed chapters on logic of experimentation and decision are presented. They are followed by six chapters giving an introduction to mathematical statistics as it applies to experimental design. Chapters on random blocks, Latin squares, field plots, power of tests in such designs, and factorial experiments, come next. Five chapters on confounding follow, then a chapter on split-plots and two on fractional replication. Six chapters on various types of incomplete block experiment, and two on groups of experiments and treatments in sequence, conclude the treatment. Tables of "F" and of the power analysis of variance, are appended. References follow each chapter.

With each major design, its mathematical model, the structure of analysis, and its efficiency, are discussed from a mathematical standpoint. Numerical examples using practical data are not abundant, but some are presented for the principal types of designs. Examples suited for assignments in teaching work do not occur.

This book should have a long period of usefulness in helping those who wish to advance in studying the basis of experimental designs.—F. M. WADLEY.

OBSERVATIONS ON THE HOMOLOGIES OF THE COPULATORY APPARATUS IN MALE COLEOPTERA[1]

STEPHEN L. WOOD

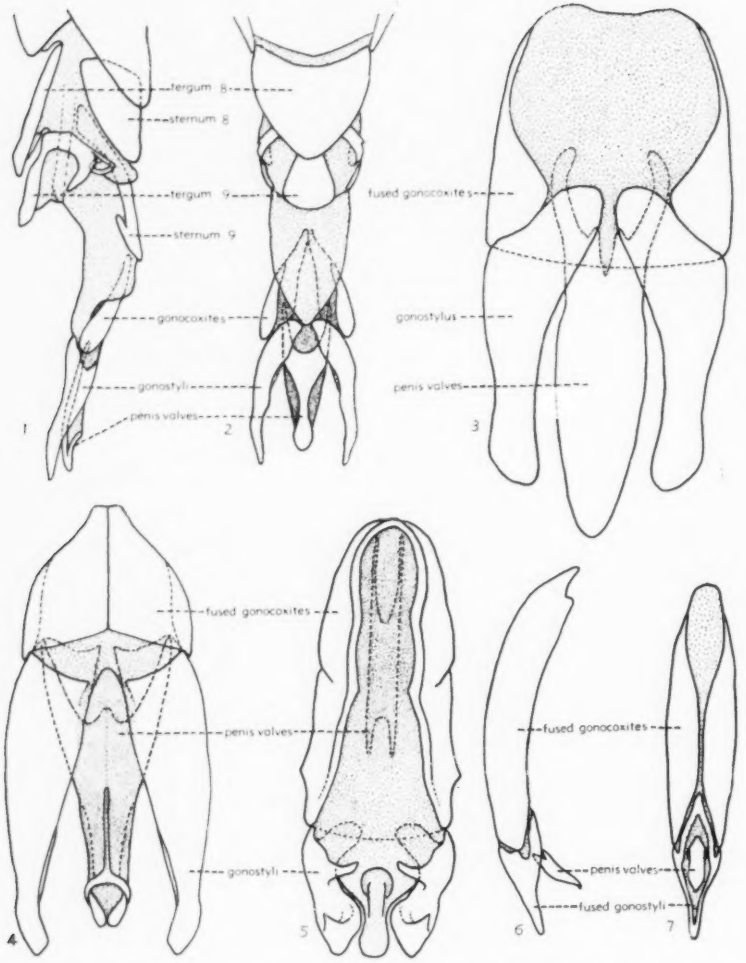
In recent years the external male genitalia have been used in insect classification with ever increasing frequency. For this reason it is continually becoming more important for the taxonomists concerned to recognize and understand the homologies of the various structures encountered. Utilizing the foundation established by Michener (1944) for attaining this objective, the purpose of this study is to point out, in a preliminary way, further homologies of the male genitalia of Coleoptera and to correlate the terms applied by Michener with those of other authors.

While the male genitalia of most insects are essentially external, they are telescoped in the Coleoptera to bring about an internal arrangement of parts. In order for the telescoping to occur, it is necessary for the membrane between sclerites to be somewhat elongate, thereby resulting in the development of a more or less loose attachment to the ninth sternum. This feature, together with the fusion of parts in the aedeagus and gonopods, has resulted in the conclusion by various authors that the genitalia of Coleoptera are entirely phallic in origin (*cf.* Snodgrass, 1935, p. 596).

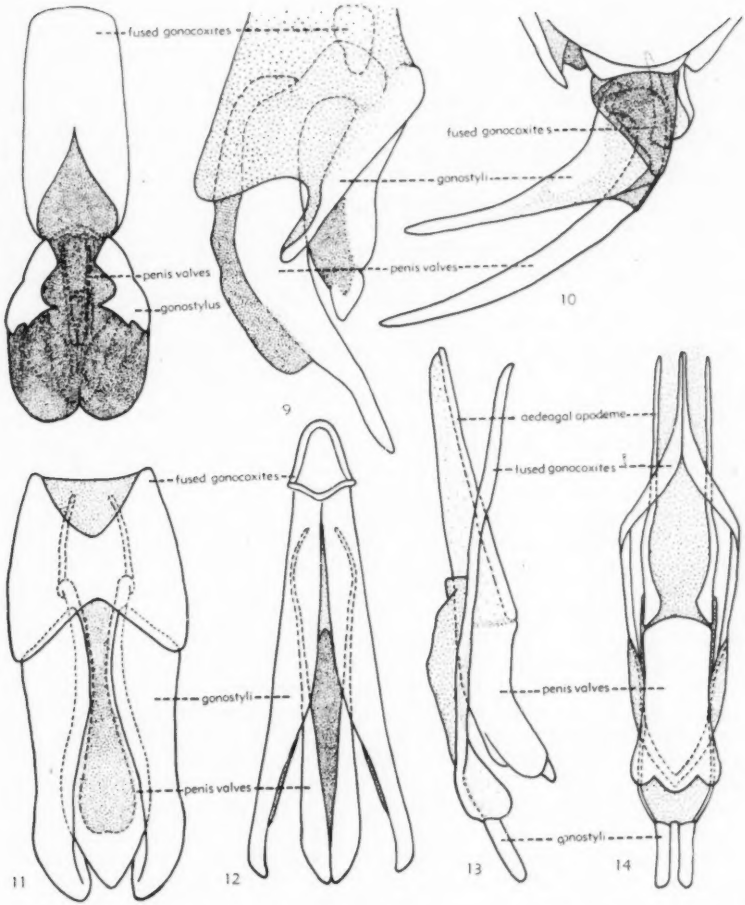
Past works treating beetle genitalia have resulted in terminology which is generally used and understood (?) only by a Coleopterist. Snodgrass, attempting to alleviate this situation, homologized many structures of the genitalia of the major insect orders. Later, Michener presumably more accurately homologized the genitalic structures of the various insect orders and redefined and clarified the morphologic terms which apply to the male copulatory apparatus. In order more readily to correlate and facilitate an understanding of the terms of Michener and other authors, the following table was prepared.

Wood	Michener	Snodgrass	Sharp and Muir
		Phallus	Aedeagus
Gonoforceps	Gonoforceps		Tegmen
Gonocoxite	Gonocoxite	Phallobase	Basal Piece
Gonostylus	Gonostylus	Paramere	Lateral Lobe
Aedeagus	Aedeagus	Aedeagus	Median Lobe
Penis Valves	Penis Valves		
Aedeagal Apodemes		Aedeagal Apodemes	Median Struts
Endophallus		Endophallus	Internal Sac
Phallotreme		Phallotreme	Median Oroface

[1]Contribution number 754 from the Department of Entomology, University Kansas, Lawrence.



The genital capsule of the copulatory apparatus in male Coleoptera. FIGS. 1 and 2. Lateral and dorsal aspects of *Hydrous triangularis* (Say), Hydrophilidae, including posterior abdominal segments. FIG. 3. Dorsal aspect of *Octinodes schaumi* (Lec.), Cebrionidae. FIG. 4. Ventral aspect of *Hydrophilus obtusatus* Say, Hydrophilidae. FIG. 5. Dorsal aspect of *Phyllophaga lenis* Horn, Scarabaeidae. FIGS. 6 and 7. Lateral and ventral aspects of Alleculidae, sp. ?.



The genital capsule of the copulatory apparatus in male Coleoptera. FIG. 8. Dorsal aspect of *Hister coenosus* Er., Histeridae. FIG. 9. Dorsolateral aspect of *Omophron dentatum* Lec., Omophronidae. FIG. 10. Ventrolateral aspect of *Rhantus flavogriseus* Cr., Dytschidae. FIG. 11. Dorsal aspect of *Trox* sp., Trogidae. FIG. 12. Dorsal aspect of *Acmaeodera connexa* Lec., Buprestidae. FIGS. 13 and 14. Lateral and ventral aspects of *Cucujus clavipes* Fab. var. ?, Cucujidae.

The gonocoxites, which are typically paired in other insect orders, are fused in the Coleoptera (except *Hydrous*, Hydrophilidae, fig. 2). The typical primitive male genitalia is illustrated by *Hydrophilus* (Hydrophilidae, fig. 4, where the line of gonocoxite fusion is visible) and *Octinodes* (Cebrionidae, fig. 3), with the ventrally fused gonocoxites forming a continuous sclerotized ventral plate and with the lateral margins turned upward leaving the trough-like structure open dorsally. Although the paired gonocoxites of *Hydrous* most nearly approach the ancestral Neuropteran type, it should not be inferred that this or the following groups are here advanced as the most primitive of the Coleoptera. (It should also be pointed out that Michener's figures 12, 13, and 14 of *Hydrous* genitalia are ventral, dorsal, and lateral respectively, not dorsal, ventral, and lateral as indicated.) From the more or less primitive gonocoxites, the general tendency in the Coleoptera appears to be toward a reducation in their relative size (Adephaga, figs. 9 and 10), or dorsal fusion (*Hister*, Histeridae, fig. 8, and *Trox*, Trogidae, fig. 11), or both (*Acmaeodera*, Buprestidae, fig. 12, *Cucujus*, Cucujidae, fig. 14, Phytophaga, and Rhynchophora). Two of these variations occur in *Trox;* in fig. 11 the gonocoxites are fused dorsally, while in fig 1 of Sharp and Muir (1912) the more primitive dorsally open type is illustrated. Dorsal fusion of the gonocoxites also occurs in the Buprestidae, but not in the allied Elateridae and Throscidae (Sharp and Muir, figs. 154–161); in the Colydidae another example is found in which they fuse dorsally in *Aulonium* (Sharp and Muir, fig. 91) but not in *Colydium* (Jeannel) and Paulian, 1944, fig. 70). Reduction in the relative size of the gonocoxites is illustrated in the Adephaga, and Phytophaga, as well as Buprestidae and Silphidae (see Sharp and Muir). The dorsal fusion and reduction in size of the gonocoxites undoubtedly has occurred independently in several lines of development. In some instances the gonocoxites are sufficiently inconspicuous to be easily overlooked, as was done by Jeannel and Paulian with the Adephaga (compare with Sharp and Muir, figs. 29–39).

The gonostyli, when present, are paired (except in Tenebrionoidea) and articulated to the posterior margins of the gonocoxites; in some instances (*Rhantes*, Dytiscidae, *Octinodes*, etc.) there is a narrow dorsal articulation with the aedeagus. The gonostyli are frequently grooved mesally to accommodate the aedeagus. They vary from the relatively large size of *Acmaeodera* (fig. 12) to complete absence in Phytophaga, Rhynchophora, and some others. In the Tenebrionoidea the gonostyli are more or less fused dorsally to form a covering for the rather small aedeagus (Alleculidae, sp. ?, fig. 6 and 7).

The aedeagus is a relatively large, curved process in the Adephaga, while the gonocoxites and in many instances the gonostyli are virtually absent. In *Hister* (fig. 8), and *Phyllophaga* (Scarabaeidae, fig. 5), however, the aedeagus is greatly reduced and normally rests telescoped between the gonocoxites. In *Cucujus* (figs. 13 and 14), Phytophaga, and Rhynchophora the aedeagus bears long anterior apodemes and swings more or less freely through the ring-like fusion product of the gonocoxites. The paired structure of the penis valves generally is easily determined, though in many instances they are completely fused.

Since it is not within the scope of this study to redescribe or attempt to reclassify the Coleoptera on the basis of the male genitalia, the reader is referred to works such as Sharp and Muir, or Jeannel and Paulian for detailed descriptions or illustrations of the genitalia of various groups. The essential point is to understand that the homologies of the genitalia can be established from family to family and from order to order, just as the wing veins, leg segments, mouthparts, etc., have been homologized. It obviously will be more satisfactory if the morphologists and systematists eventually accept a single uniform system of terminology for the genitalia of all insect orders, just as they have done for most other structures of the body.

LITERATURE CITED

Jeannel, R., and **R. Paulian.** 1944. Morphologie abdominale des coloéptères et systématique de l'ordre. Rev. Française d'Ent., 11(2): 66–110, 131 figs.

Michener, C. D. 1944. A comparative study of the appendages of the eighth and ninth abdominal segments of insects. Ann. Ent. Soc. Am., 37(3):336–355, 3 pls.

Sharp, D., and **F. Muir.** 1912. The comparative anatomy of the male genital tube in Coleoptera. Trans. Ent. Soc. London, 60: 477–642, 36 pls.

Snodgrass, R. E. 1935. Principles of insect morphology. ix+667 pp., 319 figs. McGraw-Hill Book Co., New York City.

THE APHIS GENUS PERIPHYLLUS: A SYSTEMATIC, BIOLOGICAL, AND ECOLOGICAL STUDY, by E. O. Essig and Frieda Abernathy. ix+166 pp., 43 figs., frontispiece. University of California Press, Berkeley. 1952. Price, $3.50.

This small book presents an interesting example of the difficulties that arise in the taxonomic treatment of a group of animals with complex life histories. Six years were spent in the study of the ten species of male aphids included here, but only three of them were sufficiently known ultimately to be treated in detail. As many as fifteen different forms or types of individuals, excluding the egg and the immature aestivating dimorph, may be found in the seasonal cycle of at least certain species. The most exceptional of these forms is the tiny, almost microscopic disc-like dimorph which aestivates through the hot summer and transforms, upon maturity, in the fall. A successful taxonomic treatment of such a group, therefore, involves a study of the ecology and life histories of the species, as well as the material usually treated in taxonomic studies. Considerable space is, of course, devoted to the description and illustration of many forms.—M. T. J.

EGGS OF FLOODWATER MOSQUITOES. I. SPECIES OF PSOROPHORA

(Diptera: Culicidae)[1]

WILLIAM R. HORSFALL, ROBERT C. MILES AND JOHN T. SOKATCH

Eggs of mosquitoes have been known to provide important characters for segregating smaller categories ever since the work of Falleroni, 1926, but little has been done on groups other than anophelines. That his work permitted much of our knowledge of subspeciation of *Anopheles maculipennis* Meigen of the Old World suggests this stage of other groups might be profitably examined more carefully for characters. Numerous descriptions of eggs of various species of floodwater mosquitoes exist, but little effort has been directed toward systematizing the knowledge. Such knowledge would be helpful in certain groups particularly because only females are usually collected, and often they are difficult to determine. Optical systems in the form of phase microscopes now provide convenient means for much more minute examinations of surface features of the chorion than were formerly available. The observations reported herewith serve to show how distinct are the characters that may be seen by such devices for lighting the surfaces.

Eggs of some *Psorophora* have been observed and illustrated by Goeldi, 1905, Mitchell, 1907, and Howard, Dyar and Knab, 1912. These observers noted the general appearance of the eggs and recorded some facts about the surface features of the chorion and pellicle. Their illustrations are insufficient for indicating arrangements into groups of less than generic rank.

Eggs used for recognition need not be injured when intended for rearing work because the shells may be used after eclosion of the larvae. If shells only are used the cap should be included as characteristics of the chorion near the anterior end are often the more distinctive.

Descriptions and illustrations embodied in this paper were made from eggs that contained living embryos or had had the embryos recently expressed from them. In all cases the eggs had been retained in a viable state in cages for 2 to 4 months. The eggs were deposited on cellucotton by wild-caught females identified and segregated as to species. All species were obtained from Champaign County, Illinois, or Arkansas County, Arkansas, during the summers of 1950 and 1951. The source of each species is given in Table I.

METHODS

Eggs were prepared for examination and photography in two steps. The first involved removal of all material clinging to the chorion. This was done by means of the mild abrasive action of moist filter paper. A piece of filter paper was placed on the stage of a dissecting microscope and moistened with a few drops of 50 percent ethyl alcohol.

[1]Contribution from the Department of Entomology, University of Illinois. Our thanks are herewith extended to the Department of Bacteriology, University of Illinois, for providing necessary apparatus for phase micrography.

A slight depression was formed in the field of vision by scratching the paper with a bacteriologist's inoculating needle. An egg was placed in the depression and covered with a glass cover slip. By manipulation of the cover slip the egg was made to rotate and the fibers of the paper cleared the chorion of all matter clinging to it.

The second step in preparation was that of obtaining a large flattened sheet of the chorion. This was done by mounting the egg in water beneath a cover slip. First the egg was transferred to a clean microscope slide beside a drop of clean water. One side of a no. 1 cover slip was brought up to the drop of water so that the drop ran along the glass. Then the cover slip was released so that it came to cover the egg. With the egg under observation with a dissecting microscope the cover slip was rotated until the egg ruptured and the contents were expressed.

TABLE I

MEASUREMENTS OF LENGTH AND DORSOVENTRAL DIAMETER OF EGGS OF SEVEN SPECIES OF *Psorophora*

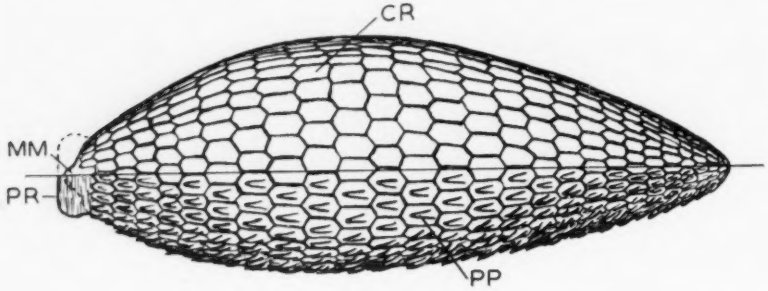
SPECIES	SOURCE	NUMBER MEASURED	SIZE IN MICRONS					
			Length			Diameter		
			Max.	Min.	Mean and SE	Max.	Min.	Mean and SE
P. ciliata Fab.	Stuttgart, Arkansas	33	911	774	822 ± 25	456	396	421 ± 13
P. howardii Coq.	Urbana, Illinois	34	831	694	781 ± 6	445	359	392 ± 4
P. varipes (Coq.)	do	33	659	548	623 ± 4	188	162	178 ± 1
P. ferox (Hum.)	do	34	788	659	723 ± 5	222	197	207 ± 2
P. horrida (D. K.)	do	32	608	548	578 ± 3	197	162	182 ± 1
P. discolor (Coq.)	Stuttgart, Arkansas	33	654	576	615 ± 3	181	155	164 ± 3
P. confinnis (L.-A.)	do	34	877	740	808 ± 5	206	189	195 ± 2

Continued rotation caused the chorion to be rent further so that a large section came to lie alone. Pressure on the cover slip at this point ruptured the larva thereby releasing fat globules. These had to be removed by draining the water and globules away by means of a strip of filter paper held to the edge of the cover glass. Final heavy pressure was applied to the cover slip by placing the heel of one hand on top of the cover slip and pushing downward. The resulting preparation was uniformly flat and free of extraneous material.

The optical system used for examination and photographing the preparations shown in Plate II consisted of a phase microscope and suitable light without filters of any sort. Magnification on the film was 450× through a 1.8-mm. objective. Most of the photographs were in phase using bright-medium contrast and dark-medium contrast. Figures 6 and 9 were made by racking the condenser downward until it was out of focus. When the condenser is lowered in this manner the point of focus is below the specimen, and only the margins are illuminated directly thus permitting reflections to shadow the surface

irregularities. Eggs with thick chorions yielded some striking results. Needless to say the features shown were verified by conventional optical means before they were photographed.

Images were recorded by means of a 35-mm. camera mounted on the microscope in the usual manner. The film was Kodak Plus X developed in a fine-grain developer. Prints were enlargments on contrast paper.



TEXT FIGURE 1

FIGURE 1. Diagram of generalized egg of *Psorophora*. Ventral half with pellicle intact, dorsal half with pellicle removed. CR, disc of reticulation of chorion; MM, micropyle mound; PP, projection of pellicle; PR, ring of pellicle surrounding micropyle mound.

DESCRIPTION

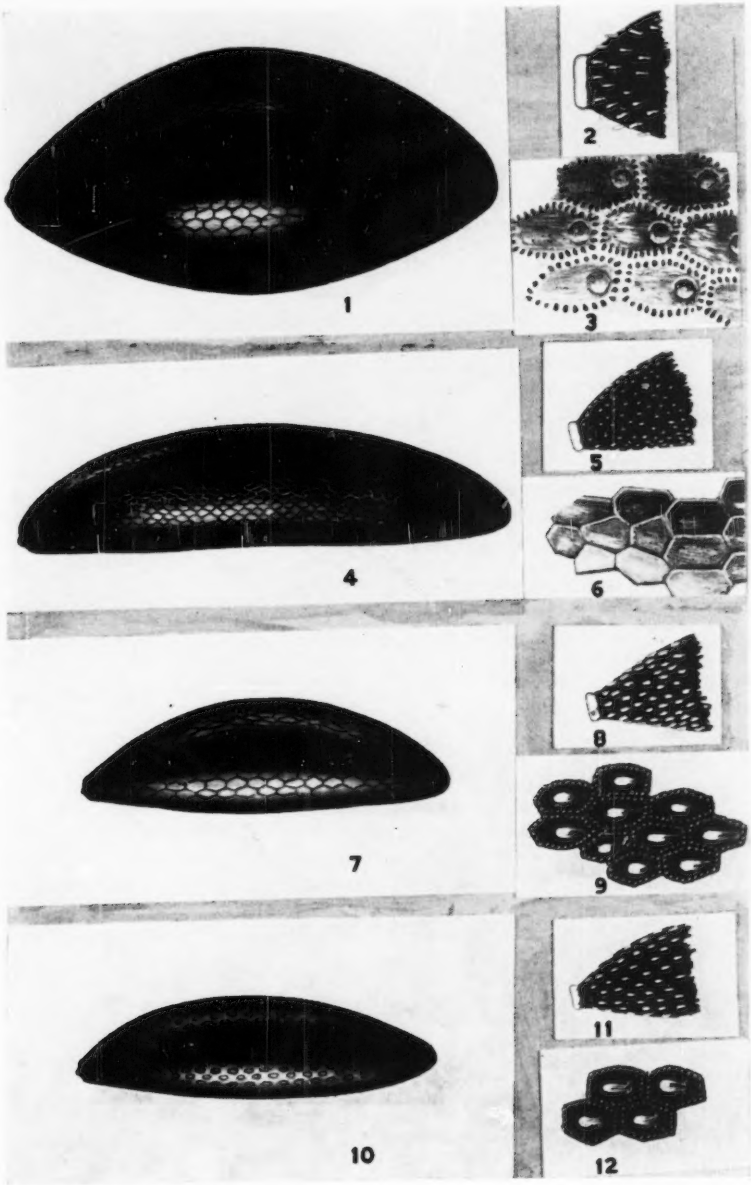
Eggs of species of *Psorophora* found in the United States are similar in gross appearance to those of other floodwater mosquitoes but differ in details. They are elongate ovoids having three general kinds of outlines as shown in Plate I. They are milk white when deposited and later appear coal black in reflected light. A single layer of chorion when seen in strong transmitted light under a microscope is brown. The chorion is marked by sculpturings of the surface. Distinctive features are usually reticulations with walls of each surrounding a central area or disc embossed in a manner characteristic of the species. Sculpturing of the chorion is best observed on the anterior third of the egg. Expansion of the egg in the center portion causes details of the chorion to be obscured. Undisturbed eggs are sheathed in a thin, brittle, transparent envelope or pellicle that seems to be distinctive for the genus. It is studded with regularly placed spiculose projections apices of which project in the direction of the anterior pole (text fig. 1).

EXPLANATION OF PLATE I

FIGS. 1–3. *P. ciliata*. 1, Lateral view of entire egg, without pellicle. × 88. 2, Lateral view of anterior end of egg, with complete pellicle. × 88. 3, View of portion of chorion at midsection, showing embossing. × 470. FIGS. 4–6. *P. confinnis*. 4, Lateral view of entire egg, without pellicle. × 88. 5, Lateral view of anterior end of egg, with complete pellicle. × 88. 6, View of portion of chorion at midsection, showing sculpturing. × 710. FIGS. 7–9. *P. horrida*. 7, Lateral view of entire egg, without pellicle. × 88. 8, Lateral view of anterior end of egg, with complete pellicle. × 88. 9, View of portion of pellicle at midsection, showing sculpturing. × 543. FIGS. 10–12. *P. discolor*. 10, Lateral view of entire egg, without pellicle. × 88. 11, Lateral view of anterior end of egg, with complete pellicle. × 88. 12, View of portion of pellicle at midsection, showing sculpturing. × 533.

Eggs of Floodwater Mosquitoes
Horsfall, et al.

PLATE I



Around the anterior pole the pellicle is gathered into a distinctly thickened ring or collar. On older eggs part or even all of the pellicle may have become removed by flaking or abrasion.

Eggs of the subgenus *Psorophora* bear features distinctly different from others of the genus. The most obvious gross difference is that the dorsal and ventral profiles are subequally convex (Pl. I, fig. 1) so that their diameters are about twice that of other species. Details for the embossing on the chorion are also distinctive features of the subgenus. The hexagonal areas are bounded by lines that are flush with the discs of those areas. The disc or center portion of each reticulation is bounded by a single row of raised dots or bosses immediately inside the walls. The rows of dots are so conspicuous that the walls become obscured (Pl. II, figs. 6 & 9).

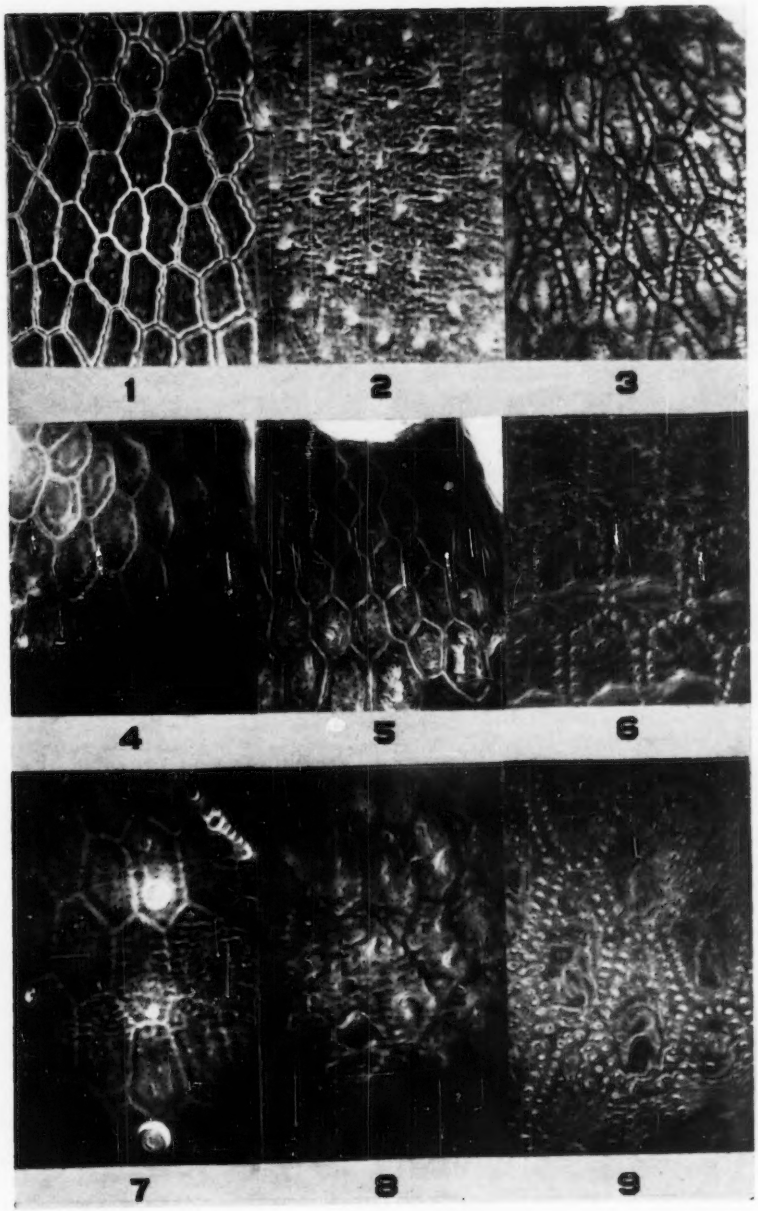
Eggs of the two species representing this subgenus in the United States are readily distinguishable from each other. Those of *P. ciliata* Fab. are the larger eggs as is shown in Table I. The row of dots bordering each disc of the reticulations forms a continuous line around the reticulation on all sides (Pl. II, fig. 9). The anterior and posterior ends of each reticulation is usually truncate rather than pointed. Each disc is marked posteriorly by a more or less smooth area shaped in the manner of a horse's hoof. Eggs of *P. howardii* have reticulations with points at the anterior and posterior ends (Pl. II, fig. 6). The row of dots bordering each disc is continuous except across the posterior sides. Each disc is marked posteriorly by a transversely ribbed raised area that is wider than long.

Eggs of the subgenus *Janthinosoma* resemble those of *Grabhamia* in profile (Pl. I, fig. 7) but differ in details of embossing on the chorion. The dorsal curvature is strongly convex while the venter is somewhat expanded medianly. Reticulations on the anterior third of the eggs are clearly defined by walls elevated above the surface. Eggs of the three species included here have walls that are flat on top (Pl. II, figs. 3–5). Eggs of *P. ferox* (Hum.) are larger than the other two of the subgenus described herewith and have discs with reticulations plain or devoid of distinctive markings (figs. 5 & 8). Walls of the surface figures are thick and distinct near the anterior end but are indistinct to wanting in the midsection of the egg. Eggs of *P. horrida* (Dyar & Knab) and *P. varipes* (Coq.) are considerably smaller than are those of *P. ferox*. Reticulations of *P. horrida* resemble those of *P. ferox* in size and shape and are smaller than those of *P. varipes*.

EXPLANATION OF PLATE II

Portions of chorion showing surface features near anterior pole (except figs. 7 and 8) as photographed with phase microscope. Magnification 787 diameters.

FIG. 1. *P. confinnis*. Lighting: bright medium contrast; exposure: 1 second. FIG. 2. *P. discolor*. Lighting: dark medium contrast; exposure: 4 seconds. FIG. 3. *P. varipes*. Lighting: dark medium contrast; exposure: 4 seconds. FIG. 4. *P. horrida*. Lighting: bright medium contrast; exposure: 4 seconds. FIG. 5. *P. ferox*. Lighting: dark medium contrast; exposure: 4 seconds. FIG. 6. *P. howardii*. Lighting: dark medium contrast, condenser focussed below field; exposure: 11 seconds. FIG. 7. *P. horrida*. Position: near middle; lighting: bright medium contrast; exposure: 4 seconds. FIG. 8. *P. ferox*. Position: near middle; lighting, bright medium contrast; exposure: 4 seconds. FIG. 9. *P. ciliata*. Lighting: dark medium contrast, condenser focussed below field; exposure: 11 seconds.


1
2
3
4
5
6
7
8
9

The disc of each reticulation is bordered by a row of shallow angular depressions that are best seen near the poles (Pl. II, fig. 4). The disc is slightly depressed and smooth. About the girth of the egg the disc is more often marked by an irregular lacework of crested ridges (fig. 7). Eggs of *P. varipes* differ from *P. horrida* in the shape of the reticulation and markings of the disc. The reticulations are larger and near the poles are usually truncate apically (Pl. II, fig. 3). The disc is marked by a U-shaped false wall making the under portion appear as a posteriorly directed finger. The border between the false and true wall is discontinuous anteriorly.

Eggs of *P. discolor* (Coq.) and *P. confinnis* (L.-A.) resemble each other very little even though they belong to the same subgenus, *Grabhamia*. Eggs of the former are very much smaller so that even the maximum length reported is considerably less than the minimum length for an egg of the latter (Table I). Those of *P. discolor* are expanded ventrally while those of *P. confinnis* have a straight or even slightly concave venter. No reticulations are evident on the chorion of *P. discolor* while those of the latter are distinctly marked over all by sharply carinate walls (Pl. I, figs. 4 & 10 & Pl. II, figs. 1 & 2). Instead of reticulations the former has the disc represented by low, wart-like excrescences surrounded by a crinkled surface. Eggs of *P. confinnis*, on the other hand, have the disc of the reticulations depressed and only faintly crinkled.

TABLE FOR RECOGNITION OF EGGS OF SEVEN SPECIES OF PSOROPHORA

1. Dorsoventral profile strongly biconvex.....Subgenus *Psorophora*. 2
   Dorsoventral profile convex dorsally, linear or faintly convex ventrally..... 3
2. Reticulations of chorion on anterior third pointed anteriorly and posteriorly; bounded anteriorly and laterally by row of nearly round, raised dots; marked posteriorly by transverse, raised, furrowed area.....**howardii**
   Reticulations of chorion on anterior third elongated and truncated anteriorly and posteriorly; bounded on all sides by two rows of raised dots; marked posteriorly by smooth, irregular area.....**ciliata**
3. Reticulations of chorion not apparent.....**discolor**
   Reticulations of chorion evident especially on anterior third..... 4
4. Walls of reticulations carinate and sharply defined over whole egg...**confinnis**
   Walls of reticulations not carinate.....Subgenus *Janthinosoma*. 5
5. Disc of reticulations on anterior third bounded by row of shallow depressions..... 6
   Disc of reticulations on anterior third unmarked; reticulations indistinct on midsection.....**ferox**
6. Walls of reticulation imperceptibly raised; disc bounded by row of very slightly raised blisters.....**varipes**
   Walls of reticulations distinctly raised on anterior third; disc bounded by row of shallow depressions at least posteriorly.....**horrida**

LITERATURE CITED

Falleroni, D. 1926. Note sulla biologia dell' "Anopheles maculipennis." Riv. di Malariol., 5: 353–380.

Goeldi, E. A. 1905. *Ianthinosoma musica* Say. *In his* Os mosquitos no Para. Mem. Mus. Goeldi, Para (Brazil). Figs. 94 and 95.

Howard, L. O., H. G. Dyar, and **F. Knab.** 1912. *P. ciliata* Fab., *P. columbiae* Dyar & Knab, *P. discolor* Coq., and *P. sayi* Dyar & Knab. *In their* The Mosquitoes of North and Central America and the West Indies, Carnegie Institute of Washington, Vol. 2, Pl. 146.

Mitchell, E. G. 1907. *P. ciliata*, *G. jamaicensis*, *G. discolor*. *In her* Mosquito Life. New York, G. P. Putnam's Sons, pp. 10–12, 216–219; Pl. VI.

A METHOD OF CLEARING THE CHORION OF AEDES SOLLICITANS (WALKER) EGGS AND PRELIMINARY OBSERVATIONS ON THEIR EMBRYONIC DEVELOPMENT[1]

JOHN D. DeCOURSEY[2]
AND
A. P. WEBSTER[2]
Department of Entomology, Naval Medical Field Research Laboratory, Camp Lejeune, N. C.

I. INTRODUCTION

Studies on the viability of mosquito eggs may require a rapid determination of the stage of embryonic development within the egg. Bates[1] states that "no special studies seem to have been made of the embryology of mosquitoes."

Where a large number of eggs are to be studied and speed is essential, the use of a microtome for sectioning to determine embryonic development is impractical. If, however, the opaque chorion of the egg could be effectively cleared to permit direct observation of the embryo, its stage of development could be readily evaluated. Mortenson (2) used a solution of five percent sodium hypochlorite to dissolve the chorion of *Aedes nigromaculis* (Ludlow) eggs, leaving the vitelline membrane intact. However, this solution would completely dissolve and destroy the mosquito egg in about six minutes.

The purpose of this paper is to present a rather simple procedure for clearing the opaque chorion of *Aedes sollicitans* (Walker) eggs, and to present a description with micro-photographs showing various stages of embryonic development.

II. THE CLEARING PROCEDURE

The chorion of the egg of *Aedes sollicitans* is white immediately following oviposition, but turns black within an hour at room temperature when deposited on a moist surface. It is this black melanin or melanin-like pigment which one wishes to clear, and the obvious choice of a clearing agent is a bleach which will not destroy the egg or the embryo within. A potent oxidizing agent is aqua regia (two parts hydrochloric acid and one part nitric acid).

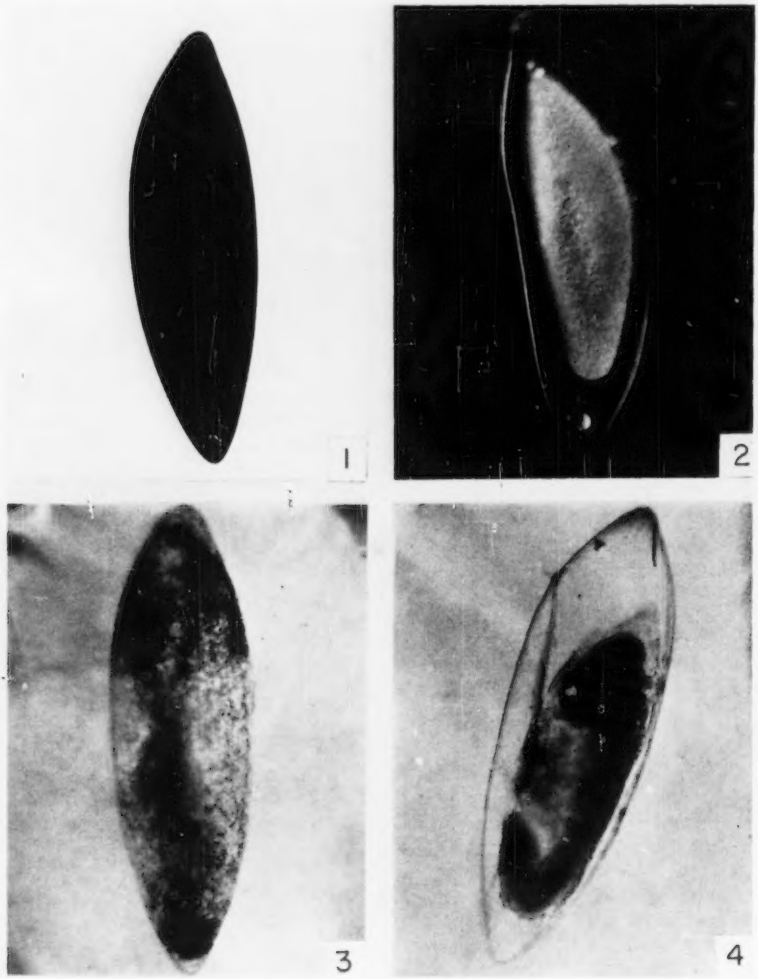
[1]The authors wish to express their appreciation to Lt. Leonard J. Bodenlos, MSC, USN; E. D. Longcope, HMC, USN; J. G. Doub, HM1, USNR; H. B. Wells, T/Sgt., USMC; P. A. Taggert, S/Sgt., USMCR; R. W. Gray, HN, USNR, for their kind assistance in the conduct of this study.

This work is not to be construed as necessarily reflecting the views of the Department of the Navy.

Cost of publication is paid by the Naval Medical Field Research Laboratory, Camp Lejeune, N. C.

[2]CDR, MSC, USN.

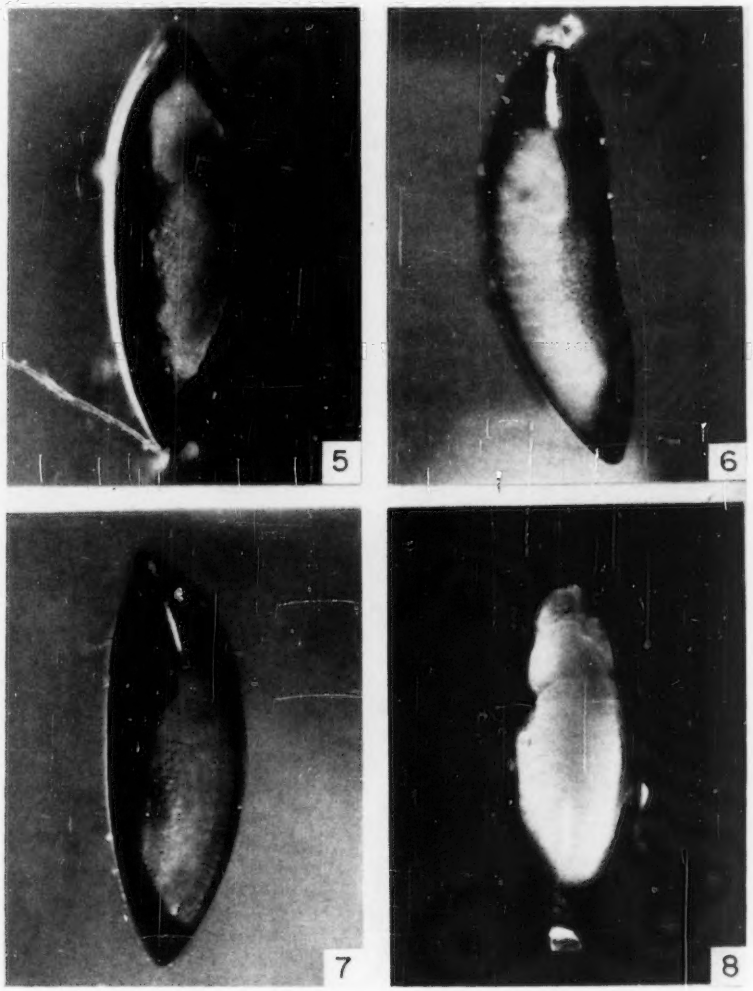
This material was found to clear the chorion effectively for subsequent study when used in accordance with the following procedure:



FIGS. 1–4. Egg and embryo of *Aedes sollicitans* (Walker), × 90. For explanation, see text.

1. The eggs to be cleared are placed in ten percent formalin as a fixative for six days or longer when subsequent dehydration and permanent slide preparation is desired. For embryonic observation only, with the eggs under water, this step may be eliminated.

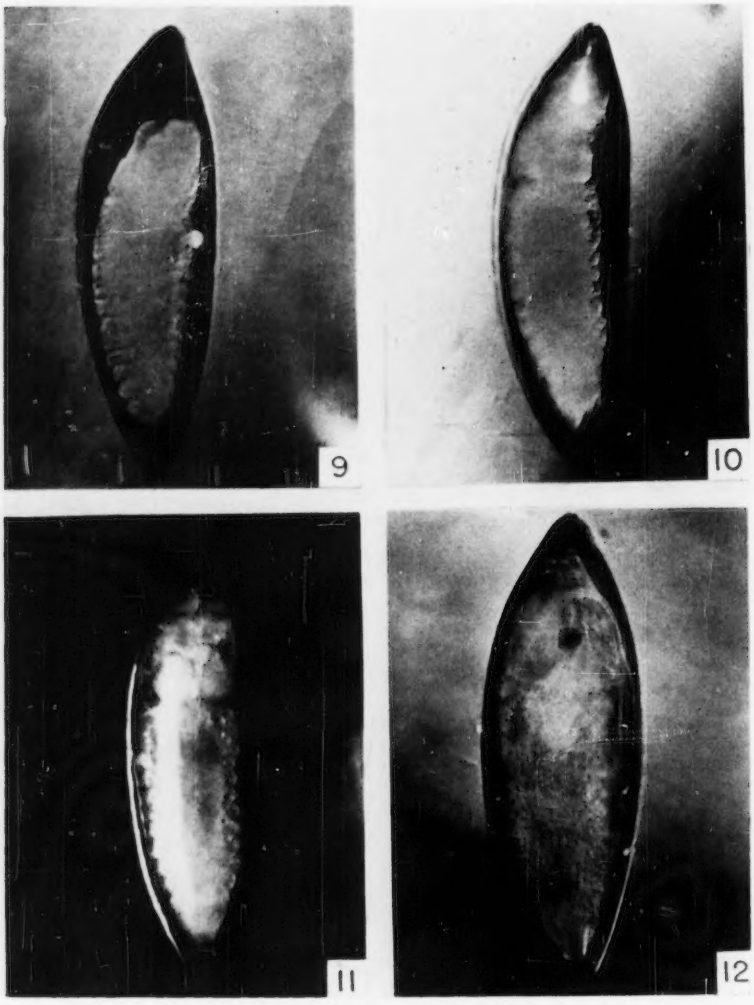
2. The eggs are then placed in an 83 percent solution of aqua regia for a maximum of five hours. The time to clear may be less and



FIGS. 5–8. Embryo of *Aedes sollicitans* (Walker), × 90.
For explanation, see text.

should be determined by observation. Before diluting, the aqua regia is allowed to stand at room temperature under an exhaust hood until all visible chemical action has stopped. If permanent slides are not being prepared, the eggs may be placed in the concentrated material for from one to two hours for immediate observation under water.

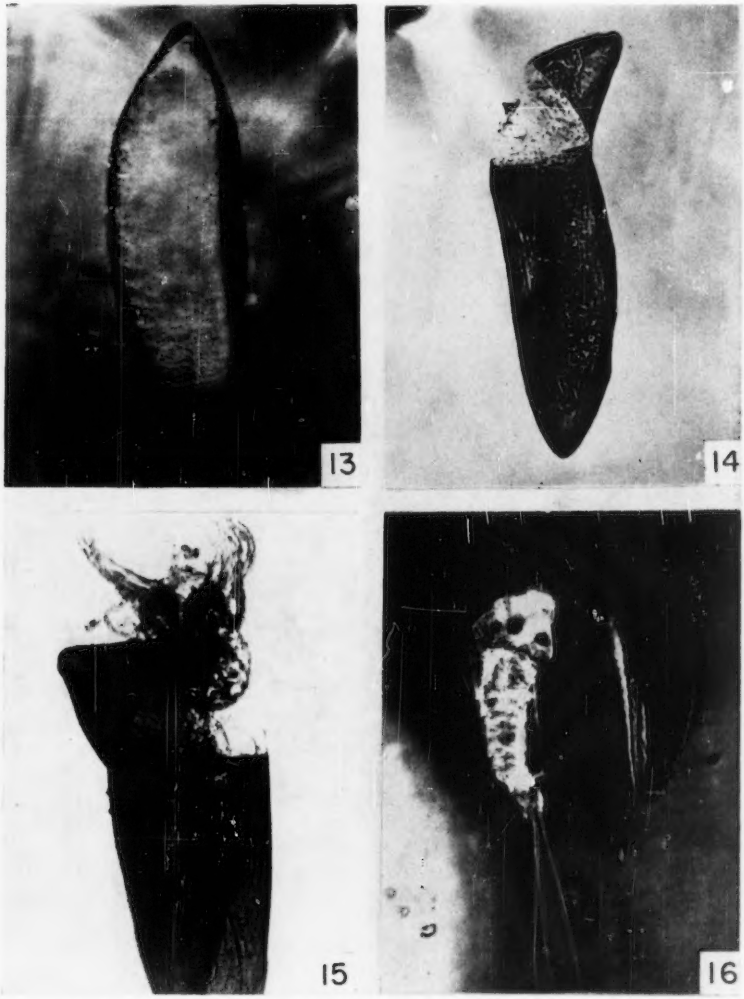
3. If the eggs are not cleared at the end of five hours, the aqua regia is removed with a bulb pipette, fresh agent is added and allowed to stand for an additional hour.



FIGS. 9–12. Embryo of *Aedes sollicitans* (Walker), × 90.
For explanation, see text.

4. The aqua regia is then carefully pipetted off until it just covers the eggs, and water is added very slowly to the stendor dishes. This process of draining and refilling with water as a wash is repeated three times at ten-minute intervals.

5. The eggs are then ready for observation or may be placed in ten percent formalin for future use.



FIGS. 13–16. Embryo and emerging larva of *Aedes sollicitans* (Walker), × 90. For explanation, see text.

The embryo is easily observed through the cleared chorion without staining. It has a brownish cast with darker segmental rings and the eye spots are red. Eggs cleared in this manner have been preserved for five months in ten percent formalin without change. If permanent

mounts of the cleared eggs are desired, they may be prepared by the following method:

1. Remove the formalin by three ten-minute changes of tap water in a stendor dish.

2. Drain half the water off the eggs with a pipette and add 25 percent cellusolve (ethylene glycol monoethyl ether) very slowly.

3. Repeat No. 2.

4. Drain all the material off the eggs with a pipette and replace with 25 percent cellusolve.

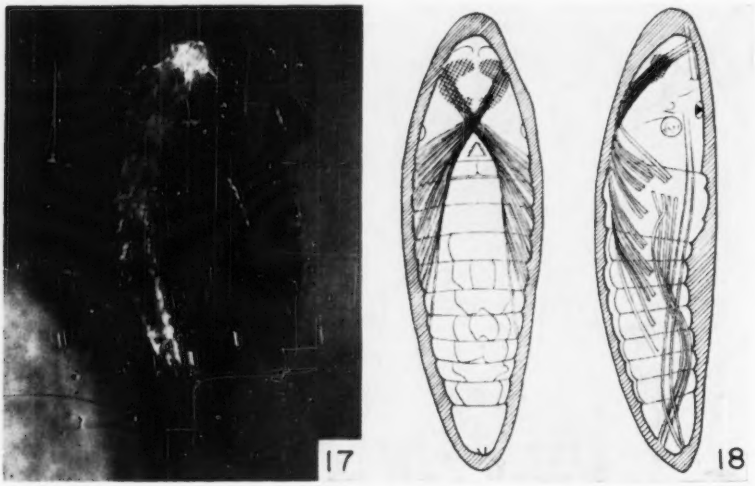


FIG. 17. Larva of *Aedes sollicitans* (Walker), killed 35 minutes after emergence. × 90.

FIG. 18. *Aedes sollicitans* (Walker): diagram of hair tuft arrangement within egg chorion. × 90. For explanation, see text.

5. Repeat No. 2 and No. 4 above for 50, 80, 95 and 100 percent cellusolve. If any shrinkage is noted in the chorion, add a drop or two of acetic acid to prevent further shrinkage, or add a drop of ammonia water to expand the chorion to its original size. When 100 percent cellusolve is reached, it should be replaced several times to insure that all the water is removed.

6. Drain half the cellusolve off and slowly add a mixture of 25 percent xylene and 75 percent cellusolve.

7. Drain all the material and repeat the process.

8. Repeat No. 6 and No. 7 above with 50 percent xylene and 50 percent cellusolve and let stand for one or more hours. Repeat with 85 percent xylene and 15 percent cellusolve, then with 95 percent xylene and 5 percent cellusolve.

9. Drain half the material and add 100 percent xylene very slowly, repeat, then drain all the material and refill with 100 percent xylene. Run through three changes of 100 percent xylene and mount on hollow ground slides in balsam.

III. THE EMBRYONIC DEVELOPMENT OF *Aedes sollicitans* (WALKER)

In order to obtain eggs of this species in various stages of development, three field collected adult females were given blood meals from a guinea pig. Oviposition was induced subsequently by exposing them in a closed jar to the concentrated fumes of ammonium carbonate for sixty seconds. Eggs were produced at the approximate rate of one every three minutes from each female. The eggs were then placed in nutrient water containing a small amount of dog food. Embryonic development was halted at various times during the next six days by placing a portion of the eggs in ten percent formalin, except the egg sample removed at the end of the first two hours which was placed immediately in aqua regia.

On the tenth day after the initial oviposition all the egg samples were removed from the formalin and the method previously described for clearing followed.

Some of the eggs produced from the three test mosquitoes were not cleared but were retained on moist paper for six days (144 hours) and then placed in distilled water to demonstrate complete embryonic development. Many hatched in a short time (overnight).

The following is a brief description of the embryonic development of *Aedes sollicitans* as observed in cleared eggs, and shown with somewhat less detail in the accompanying micro-photographs:

FIGURE	AGE OF EGGS, HOURS	REMARKS
1	—	Normal black egg, uncleared.
2	2	No development evident, egg contains protoplasm and deutoplasm.
3	18	Shadows appear, believed to indicate slight embryonic development. Shadows are larger in anterior portion of egg and extend to posterior portion.
4	43	Lateral view showing embryonic development with cellular formation. Embryo is horseshoe-shaped apparently bending backward toward the dorsal side almost forming a belt around the yolk, with a broader head region and a narrower posterior region. Segmentation of the abdomen is present and invagination is present in the head region. The thin non-cellular vitalline membrane surrounding the embryo is clearly seen.
5	53	Lateral view. Embryo has straightened within the shell. Segmentation of abdomen is more prominent. Invagination in posterior region appears.
6	77	Lateral view. Segmentation appears in the head region. Thoracic and abdominal segmentation is prominent although no definite thoracic area has been differentiated.
7	91	Lateral view. Segmentation prominent. Large mass of material (yolk) still present. Posterior invagination more definite.
8	98	Ventral view. Segmentation prominent. Head region differentiated. Invagination on ventral side of head region prominent.
9	115	Lateral view, showing differentiation of head, thorax and abdomen. Invagination in head still prominent.

FIGURE	AGE OF EGGS, HOURS	REMARKS
10	123	Lateral view. Embryonic development almost completed. Dorsal hatching spine appears as a clear protrusion midway of the head area. Eye spots appear prominently in red color at this stage but do not show in photograph.
11	123	Dorsal view. Segmentation of thorax has almost disappeared on dorsal aspect.
12	144	Dorsal view. Fully developed embryo; black hatching spine prominent on mid-dorsal portion of head.
13	144	Lateral view. Fully developed embryo showing hatching spine.
14	144	Chorion punctured and split by the dorsal hatching spine.
15	144	Larva emerging from egg.
16	...	Larva killed sixty seconds after emergence from egg. Note that the segments have been pushed together similar to an accordion while within the egg.
17	...	Another larva killed 35 minutes after emerging from egg. Note expansion to normal size which is considerably longer than egg shell.
18	144	Diagram of hair tuft arrangement within egg chorion. In the fully developed embryo the thoracic and abdominal hair tufts form a definite pattern. The lateral hair tufts (thoracic and abdominal) are quite long at this stage, and, arising from each hair-producing segment, extend ventrally and forward on either side. They cross on the ventral side between the thorax and the head, thence over the mouth brushes to the anterior part of the head. The hairs on the second segment of the thorax dorsad of the lateral hair tufts are directed caudally on either side ending near the tip of the abdomen on the ventral side. Conversely, the tufts on the anal segment extend anteriorly on each side and end on the lateral side of the head between the eyes and the dorsal spine. The position of these hair tufts can easily be seen through the chorion of a cleared egg.

IV. SUMMARY

Aqua regia has been found to be an agent for clearing the opaque chorion of the eggs of *Aedes sollicitans* (Walker). The detailed procedure described employs the following general steps: (a) treatment with aqua regia, (b) washing, (c) then immediate observation, or (d) treatment with formalin for future observation, or, (e) washing and treatment with cellusolve and xylene for permanent mounting.

The clearing procedure was used to study the embryonic development of *Aedes sollicitans* (Walker) by terminating the development of the eggs with formalin at various times, clearing the chorion, and subsequent observation of the embryos. Micro-photographs were made.

REFERENCES

1. **Bates, M.** 1949. The Natural History of Mosquitoes. Macmillan Co.
2. **Mortenson, E. W.** 1950. The use of sodium hypochlorite to study *Aedes nigromaculis* (Ludlow) embryos (Diptera: Culicidae). Mosquito News, 10(4): 211–212.

THE HOMOLOGIES OF THE MALE GENITALIA OF RHYNCHOPHORA AND ALLIED COLEOPTERA[1]

EDWARD E. GILBERT

The purposes of this paper are to emphasize the homologies of the male genitalia of the Rhynchophora and allied Coleoptera, to correlate these findings with those of Wood (1952) concerning Coleoptera as a whole, and to establish a terminology for the structures in accord with the interordinal homologies of genital parts suggested by Michener (1944). Various representatives of the cucujid-Phytophaga-Rhynchophora series have been examined, and selected examples are illustrated in the accompanying figures. The illustrations presented by Sharp and Muir (1912) and Jeannel and Paulian (1944) make other figures unnecessary here.

The terminology of parts here employed is that of Wood (1952), who presents a table correlating this system with that of other authors. It will suffice to say that the term *gonocoxite* (Michener) has been substituted for the "basal piece of the tegmen" (Sharp and Muir), the term *gonostylus* for the "lateral lobe of the tegmen," and *aedeagus* for the "median lobe." The aedeagus is a composite structure including the penis and penis valves which are fused in Coleoptera.

A number of publications have pointed out possible trends of the cucujid-Phytophaga-Rhynchophora series. Muir (1919) showed the tendency of the aedeagus (median lobe) to elongate at two areas to form aedeagal apodemes (Snodgrass, 1935) that serve as attachments for the retractor muscles that actuate the endophallic sac (Snodgrass, ibid.), and of the gonocoxites and gonostyli (tegmen) to become reduced to a slender ring or "Y" in the Rhynchophora. Pu (1938), illustrating the musculature of several male Coleoptera, points out that the adductors and abductors of the gonostylus, when present (*Cybister*, *Hydrous*, *Melanauster*), originate on the aedeagal apodemes (median struts). That these muscles are invariably inserted on the gonostyli (lateral lobes) would indicate that when the tegmen is reduced as in *Cybister* and *Melanauster* the remnant consists of the fused gonostyli. Pu's statement, "Many peculiar muscles were found in the genitalia of different species," and the series studied, tend not to support this possibility as strongly as the one outlined below involving the reduction of the gonostyli, their loss as articulating sclerites and fusion with the gonocoxites. To illustrate the latter possibility it should be noted that in *Cucujus*, Cucujidae (figs. 3-A, 3-B) in which the lateral aedeagal apodemes are already apparent as a fused elongation of the aedeagus, the gonocoxites are fused both dorsally and ventrally around the aedeagus in an elongate slanting ring, with the gonostyli persistent. For the series under consideration this represents the primative type,

[1]Contribution number 777 from the Department of Entomology, University of Kansas, Lawrence, Kansas.

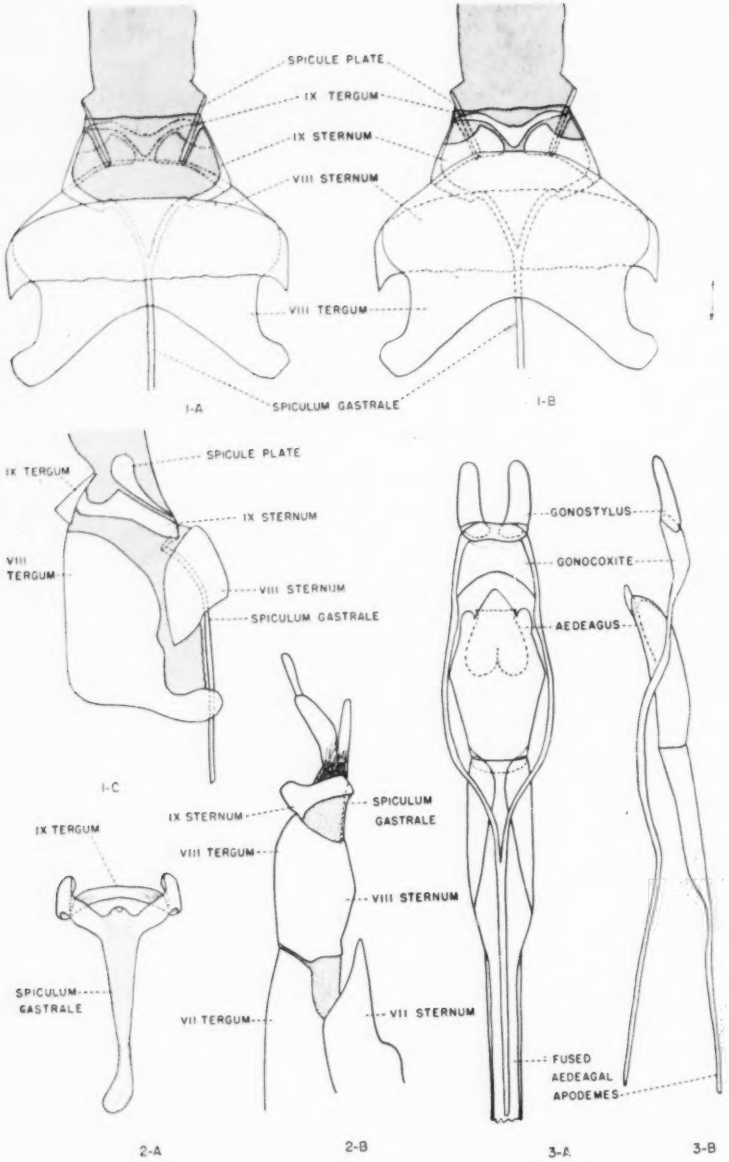


FIG. 1. *Temnochila virescens* (Fab.), eighth and ninth abdominal segments of male. A, ventral view; B, dorsal view; C, lateral view. FIG. 2. *Cucujus clavipes* Fab., male. A, ventral view of ninth abdominal segment; B, lateral view of seventh, eighth, and ninth abdominal segments with genitalia extended. FIG. 3. *Cucujus clavipes* Fab., gonopods and aedeagus of male. A, ventral view; B, lateral view.

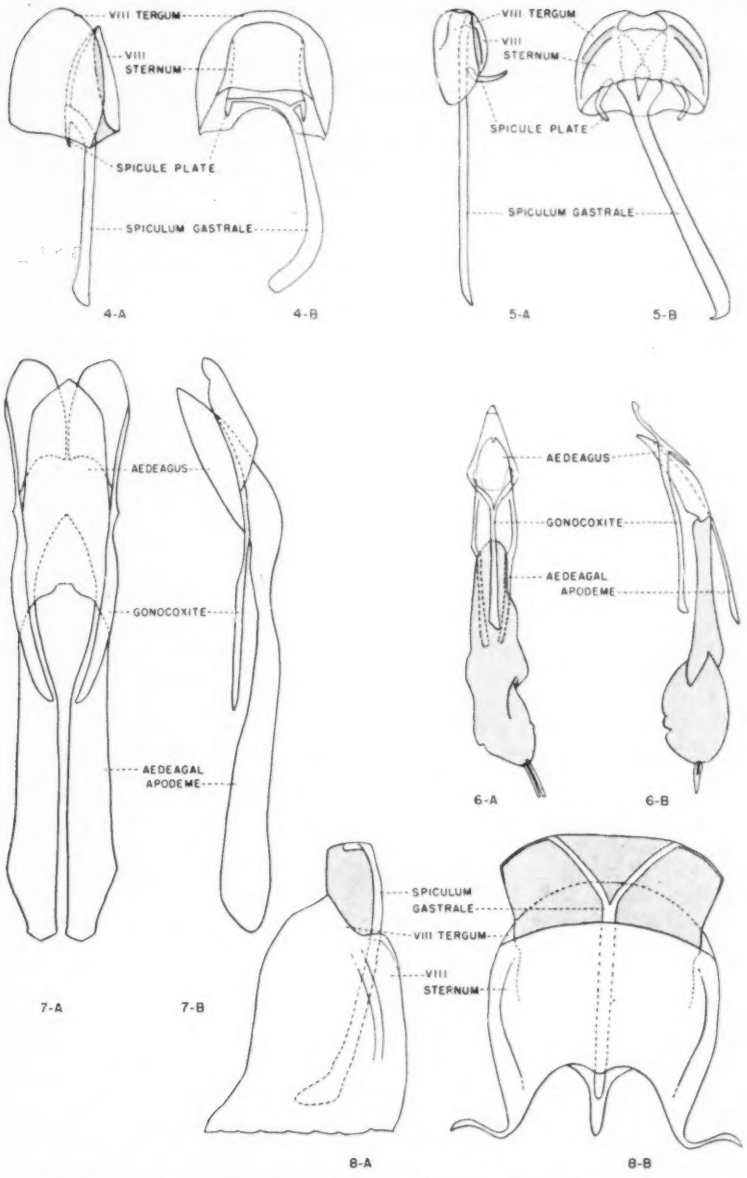


FIG. 4. *Cossonus impressifrons* Horn, eighth and ninth abdominal segments of male. A, ventral view; B, lateral view. FIG. 5. *Eugnamptus collaris* (Fab.), eighth and ninth abdominal segments of male. A, lateral view; B, ventral view. FIG. 6. *Eugnamptus collaris* (Fab.), gonopods and aedeagus of male. A, ventral view; B, lateral view. FIG. 7. *Parandra brunnea* (Fab.), gonopods and aedeagus of male. A, ventral view; B, lateral view. FIG. 8. *Parandra brunnea* (Fab.), eighth and ninth abdominal segments of male. A, ventral view; B, lateral view.

in which all parts of the gonopod are present, although the gonocoxites are radically modified and fused to form a ring. In *Parandra*, Cerambycidae (figs. 7-A, 7-B) the lateral aedeagal apodemes are separate, the slanting elongate ring is still present, but the gonocoxites forming the ring are fused only ventrally, the dorsal separation being probably secondary. The gonostlyi are not present as articulating structures although the posterior part of the gonocoxite is broadened laterally. The last in the series is *Eugnamptus*, Curculionidae (figs. 6-A, 6-B), in which the gonostyli are wholly wanting and the ring formed by the gonocoxites is nearly vertical in position and thus reduced in size. This reduction may continue until in some of the Brachyrhinini a dorsal Y- or U-shaped structure (Bruhn, 1947), much reduced in size proportionately, is all that is seen of the fused gonocoxites.

The ninth tergum and sternum are fused in most Coleoptera as in most other insects to form a complete ring. Accompanying the reduction of the gonopods is a parallel reduction of the sclerotic portions of the ninth segment. This reduction is mentioned by Snodgrass (1935) in the Scarabaeidae, and illustrated by Jeannel and Paulian (1944) in a series of illustrations including a catopid and curculionid as extremes. Jeannel and Paulian's plates reveal the semblance of a spiculum gastrale in the ninth sternum of *Nargas anistomoides* Spence, Catopidae; the elongation of this spiculum gastrale anteriorly in *Adelops hirtus* Tellkamph, Catopidae, and finally the formation of the spiculum gastrale in *Ectemnorrhinus viridis* G. R. Wat., Curculionidae. The homology of the spiculum gastrale with the ninth sternum is further demonstrated below in a different series, in which *Temnochila*, Ostomidae (figs. 1-A, 1-B, 1-C) follows in a developmental trend the primative *Nargas* illustrated by Jeannel and Paulian. In *Temnochila* a definite elongate spiculum gastrale projects from the anterior end of the ninth sternum. The spiculum gastrale in *Cucujus* (figs. 2-A, 2-B) is split into three sclerotized parts, the lateral portions having become secondarily separated by membrane from the medial part. The dorsum of the ninth segment of *Parandra* (figs. 8-A, 8-B) has entirely disappeared as a sclerotized structure, and the fork-shaped spiculum gastrale is the sole remnant of the ninth sternum. The spiculum gastrale continues as a forked structure in *Eugnamptus* (figs. 5-A, 5-B) and may be reduced to a rod as in *Curculio* (Bissell, 1937) or become elbowed as in *Cossonus*, Curculionidae (figs. 4-A, 4-B), and some of the scolitids. The intersegmental membrane, originating at the posterior part of the eighth sternum, and extending in the more primative forms examined (*Cucujus* and *Temnochila*) to the posterior part of the ninth segment, has shifted anteriorly with the reduction of this segment to the posterior arms of the spiculum gastrale in *Parandra* and the Rhynchophora. This shift of the membrane (or desclerotization of the disc of the sternum) would be expected when the spiculum is considered the remnant of the ninth sternum.

Bissell noted in *Curculio*, Curculionidae, dorsad to the posterior end of the spiculum gastrale, a pair of structures, the spicule plates, that act as a sliding surface for the aedeagus. These paired sclerotized structures are present in *Temnochila* (figs. 1-A, 1-B, 1-C), *Eugnamptus* (figs. 5-A, 5-B), and *Cossonus* (figs. 4-A, 4-B), but not in *Parandra*

and *Cucujus*. The position of the spicule plates is relatively the same when present, except in *Cossonus* where they are fused directly to the spiculum gastrale instead of lying in membrane. The spicule plates may originate from the ninth segment, like the spiculum gastrale, and with the reduction of the ninth segment remain as supporting remnants.

ACKNOWLEDGMENTS

Many of the conclusions presented in this paper were reached in cooperation with Mr. Stephen L. Wood. Discussions of many problems with him proved valuable to both of us. Thanks are also due to Dr. Kathleen C. Doering and Dr. Charles D. Michener for aid in the study and in the preparation of this paper.

LITERATURE CITED

Bissel, Theodore. 1937. Structure of the reproductive system of the pecan weevil. Ann. Ent. Soc. Amer., 30: 242–252.

Bruhn, A. F. 1947. The external genitalia of some Rhynchophora. Great Basin Nat., 8: 1–35.

Jeannel, R., and **R. Paulian.** 1944. Morphologie abdominale des coléoptères et systèmatique de l'order. Rev. Française d'Ent., 11: 66–110.

Metcalf, M. E. 1932. The structure and development of the reproductive system in the Coleoptera. Quart. Jour. Micr. Sci., 75: 49–129.

Michener, C. D. 1944. A comparative study of the eighth and ninth abdominal segments of insects. Ann. Ent. Soc. Amer., 37: 336–351.

Muir, F. 1918. Notes on the ontogeny and morphology of the genital tube in Coleoptera. Trans. Ent. Soc. London, 9: 223–231.

1919. On the mechanism of the male genital tube in Coleoptera. Trans. Ent. Soc. London, 10: 404–414.

Pu, C. 1938. A comparative study of the musculature of the male genitalia in several species of Coleoptera. Lingnan Sci. Jour., 17: 21–31.

Sharp, D., and **F. Muir.** 1912. The comparative anatomy of the male genital tube in Coleoptera. Trans. Ent. Soc. London, 60: 447–642.

Sharp, D. 1918. Studies in Rhynchophora, IV, A preliminary note on the male genitalia. Trans. Ent. Soc. London, 9: 209–222.

Snodgrass, R. E. 1935. Principles of insect morphology. ix+667 pp. McGraw-Hill, N. Y.

Wood, S. L. 1952. Observations on the homologies of the copulatory apparatus in male Coleoptera. Ann. Ent. Soc., Amer., 45: 613–617.

LONGICORNIA, ETUDES ET NOTES SUR LES LONGICORNES, by P. LEPESME (Editor). Vol. II. Paul Lechevalier, Paris. 1951.

The second volume of this periodical is devoted entirely to a lengthy work on the longicorn beetles of China, by J. Linsley Gressitt, in which the author attempts "to bring together the information on the subject in a condensed form and to offer brief keys for the identification of the species," although "the very incomplete stage of our knowledge . . . makes a monograph of the fauna impossible at this time." The work runs to 667 pages, with the descriptions of numerous new forms and with host and insect indexes; it is illustrated with a map of the Chinese provinces and with 22 plates of drawings of adult and larval beetles.

—M. T. J.

STUDIES OF AN INSECT MYCOSIS. V. COLOR CHANGES ACCOMPANYING PARASITISM IN PLATYSAMIA CECROPIA[1,2]

ALFRED S. SUSSMAN

Department of Botany, University of Michigan
Ann Arbor, Michigan

The morphological and histological changes in cercopia moths (*Platysamia cecropia L.*) parasitized by *Aspergillus flavus* Link have been reported in previous papers (Sussman 1951a, b). During these investigations it was noted that trauma or disease usually caused the blackening of the insect's integument and blood, in agreement with many previous observations (v. Fürth and Schneider 1901; Schlottke 1926; Bhagvat and Richter 1938). Such blackening is due to the action of the enzyme tyrosinase which is almost universally present in insects and which is considered to play an important role in their respiration and structural development (Heller 1947; Sussman 1949). It was to determine the reasons for this color change and its relation to the disease process that these investigations were undertaken.

MATERIALS AND METHODS

The animals used were intact or brainless dispausing pupae of *Platysamia cecropia* L., or pupae with posterior windows, prepared as described by Williams (1946) and Sussman (1951a). Infection was usually accomplished by injecting 0.05 ml. of a heavy aqueous suspension of condia of *Aspergillus flavus* Link directly into the animal's body cavity with a sterile hypodermic syringe and a needle with a diameter of approximately 0.017 cm. In order to minimize loss of blood due to the animal's movement, the needle was inserted laterally into the thoracic intersegmental membrane and was withdrawn very carefully, after injection of the chemical.

The effect of various substances upon the coloring of the insect's blood was determined by introducing the chemicals into the body cavity before the posterior window was sealed into place. Changes in the color of the blood were then observed through the plastic window.

RESULTS

The first problem investigated was whether or not blackening was a necessary accompaniment of death in the cecropia moth. With this in mind, experiments were performed in order to determine whether it was possible to prevent the blackening reaction in healthy animals by inhibiting tyrosinase.

[1]Portion of thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Harvard University.

[2]The author would like to express his gratitude to Dr. William H. Weston for his sympathetic and stimulating direction of this work. I should also like to state my appreciation for the cooperation and help given by Dr. Kenneth V. Thimann and Dr. Carroll M. Williams during the course of these investigations.

Therefore, chemicals known to inhibit the enzyme or to prevent the accumulation of melanins were introduced into animals which had posterior windows as described in the previous section. The results showed that the injection of sterile water alone failed to prevent the blackening reaction since pupae which had received such treatment blackened within 12 hours after the operation on their abdomen had been performed (fig. 1). Similarly, salicylaldoxime (SA) failed to inhibit this reaction. On the other hand, phenylthiourea (PTU), sodium diethyldithiocarbamate (NDC), thiouracil (TUO) and ascorbic

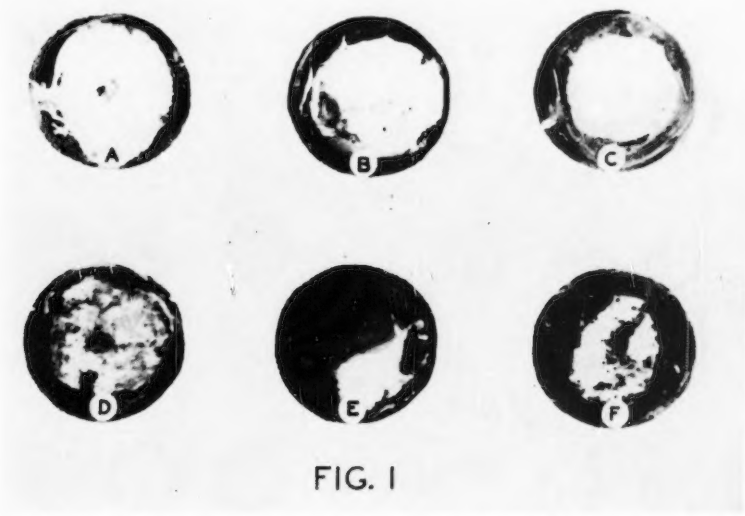


FIG. 1

FIG. 1. Appearance of the body cavity of uninfected pupae of *P. cecropia* as viewed through posterior windows 24 hours after the addition of certain chemicals to prevent blackening of the blood.

KEY

Animals	Chemicals Added	Effect on the Prevention of Blackening
A	Phenylthiourea	+
B	Sodium diethyldi-thiocarbamate	+
C	Ascorbic acid	+
D	Thiourea	+
E	Salicylaldoxime	—
F	Sterile water	—

acid (ACO) proved to be quite effective in preventing blackening of the blood of these animals after drastic trauma. These compounds appeared to be relatively benign in their effect upon the other activities of the animal since pupae treated in this way matured quite normally.

Having determined the effect of these inhibitors upon tyrosinase and the blackening reaction in the uninfected animal, it was now possible to extend the experiments to include their effect upon infected animals.

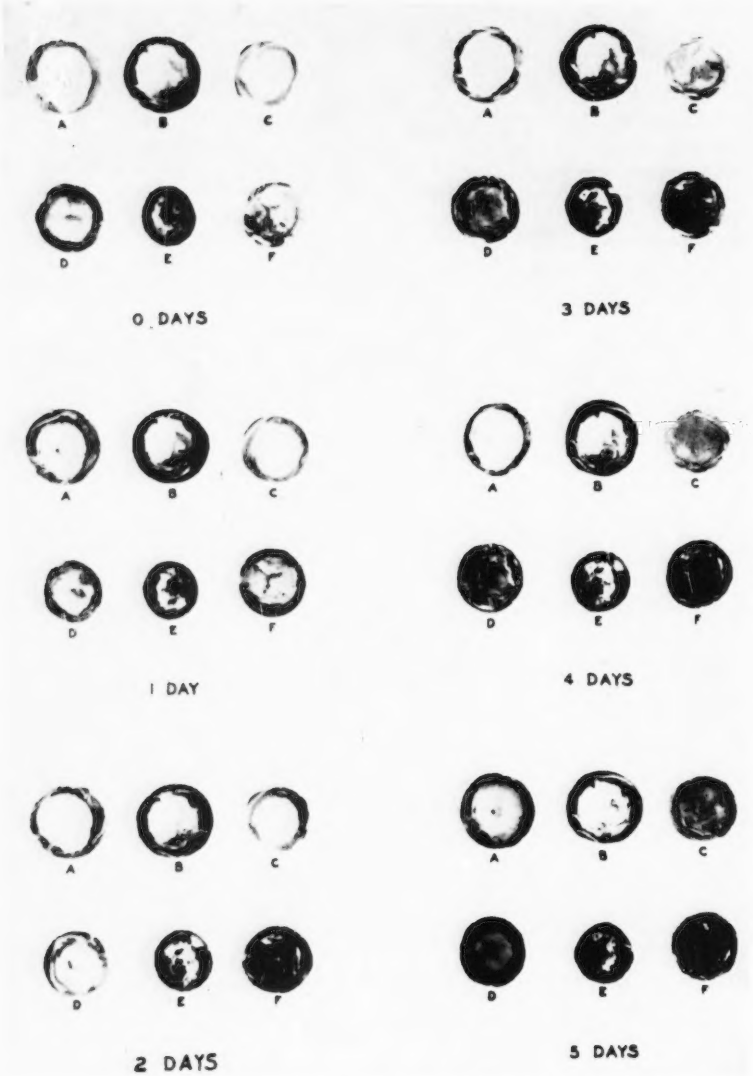


FIG. 2. Appearance of blood of pupae of *P. cecropia*, as viewed through posterior windows at daily intervals after inoculation with *A. flavus*. The number under each set of figures denotes the time of photography, in days after inoculation. The letters represent animals receiving the following treatment:

Animal	Substances Injected	Color at the End of Five Days
A	Phenylthiourea; spores	Normal
B	Sodium diethyldithiocarbamate; spores	Normal
C	Ascorbic acid; spores	Brown
D	Thiouracil; spores	Brownish-black
E	Sterile water	Black
F	Water;spores	Black

Note that the blood of animals treated with ascorbic acid and thiouracil remained uncolored for 2 days following their inoculation, but gradually darkened thereafter.

Essentially the same techniques were used in these experiments as were used in the preceding ones, except that a spore suspension of *A. flavus* in distilled water was introduced simultaneously with the chemicals. Moreover, salicylaldoxime was not used in these experiments since it

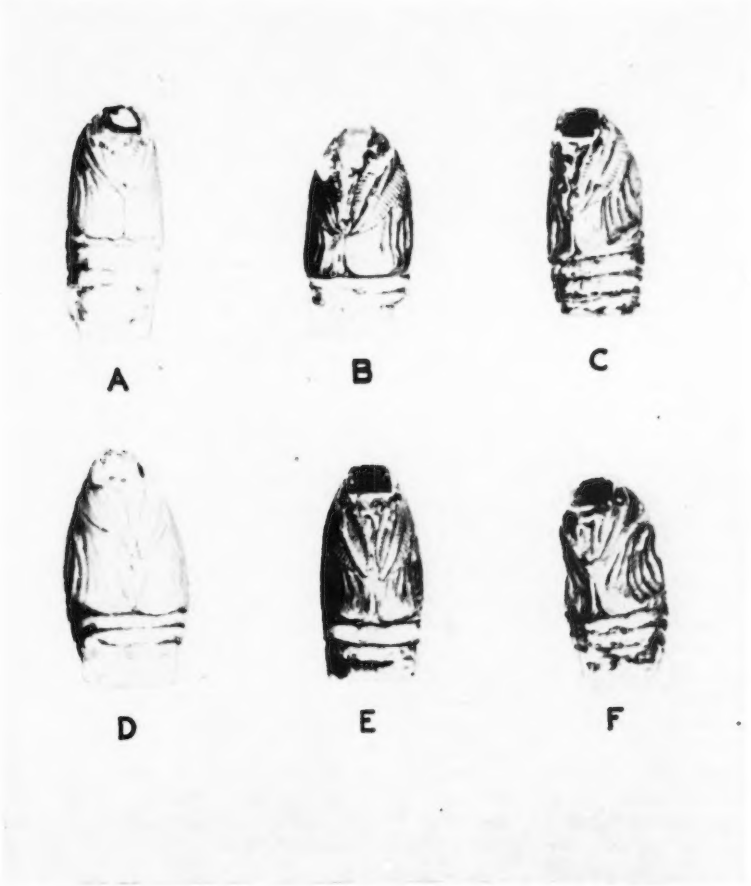


FIG. 3. Pupae of *P. cecropia* as in figure 2, except that viewed laterally, 5 days after inoculation with *A. flavus*. Note how the integument of animals A and B has shrunken as a result of parasitism, despite the fact that their blood has not yet blackened. App. nat. size.

had been shown to be ineffective in preventing blackening in the uninoculated animal. It can be seen from the results of the experiments, as illustrated in figures 2 and 3, that again the sterile water controls, both uninoculated and inoculated, began to blacken within a few hours after the operation upon their abdomens was performed.

The changes in the blood of these animals could be observed by direct observation through the facial window. The uninoculated controls, at the end of 5 days, darkened only slightly more than they had on the first day, and were alive and seemed healthy. On the other hand, the inoculated control continued to darken after infection until, at the end of 5 days, its entire body cavity and integument had turned black (figs. 2 and 3). These animals were assumed to be dead since they did not respond to stimuli such as pin pricks, while their abdomens developed the rigidity characteristic of the later stages of this fungous infection.

Although the blood of the control animals darkened very rapidly after inoculation and the operation upon their abdomens, the blood of the infected animals which had been treated with chemical inhibitors retained their original color for a much longer time (figs. 2 and 3). For example, the color of those animals which had been treated with PTU and NDC appeared to be normal even after 5 days of infection with the fungus. To be sure, the blood of the animals treated with thiouracil and ascorbic acid showed conspicuous darkening after 3 days, but it was obvious that the blackening process had been inhibited to some extent. All the inoculated animals appeared to be dead at the end of 5 days so that the experiment was concluded at that time.

The fact that the inhibiting effect of thiouracil and ascorbic acid on blackening was reversed after two days suggested that this might also prove to be the case for phenylthiourea and sodium diethyldithiocarbamate if enough time were given for this reversal to occur. Consequently, another series of experiments were conducted using these two compounds, in order to inhibit the blackening of infected pupae. Observations were made daily for a period of about 2 weeks, and it was discovered that all the animals blackened 8 days after infection. At this time the animals had shrunken considerably, and it was obvious that they had been dead for some time before blackening had occurred.

Since it is known that phenols are oxidation products of reactions catalyzed by tyrosinase, and since it is known that such compounds may be toxic to *P. cecropia* in high concentrations (Sussman 1952b), it was decided to investigate the changes in the content of phenolic compounds resulting from the development of the disease.

In order to investigate these changes, the blood of both healthy and infected chilled diapausing pupae was analyzed qualitatively for its content of phenols and phenolic amino acids by the use of the tests suggested by Lison (1936) and Feigl (1937). Blood was obtained by puncturing the animal's intersegmental membrane and was tested immediately in order to minimize autolysis of the blood proteins. To some extent, by the intensity of the coloring reaction, it was possible to gain an approximate quantitative evaluation of the relative concentrations of the substances investigated. These concentrations were expressed by the symbols +, − and −− and the results presented in Table I.

These results strongly indicate that the blood of the uninoculated healthy pupa of *P. cecropia* contains tyrosine, a monophenolic amino acid, while polyphenols appear to be almost entirely lacking. On the other hand, the blood of diseased animals is seen to contain both tyrosine and polyphenols. That ortho phenols are probably present

in these animals is shown by the fact that the ferric chloride test is positive (Vogel 1948; Lison 1936). These compounds do not appear until after the first day of the infection, but thereafter seem to accumulate in some quantity since the reaction of the blood to the tests for these compounds becomes much stronger at this time.

TABLE I

CONTENT OF PHENOLIC COMPOUNDS OF BLOOD OF INFECTED AND UNINFECTED PUPAE OF *P. cecropia*

TEST	RETRACTIVE GROUPS	NON-INFECTED ANIMALS	INFECTED ANIMALS Time After Infection		
			1 Day	2 Days	3 Days
Millon's	Tyrosyl Residues				
	Tyrosine	+	+	+	+
Ninhydrin	Amino Acids	+ +	+	+	+
Alloxan	Amino Acids	+	+	+	+
Argentaffin	Polyphenols	+			
	(Para or Ortho)	—	±	±	+ +
Chromaffin	Polyphenols	—	±	±	+ +
Ferric Chloride	Ortho-Phenols	±	+	+	+ +

DISCUSSION AND CONCLUSIONS

In view of the foregoing, it must be concluded that phenylthiourea and sodium diethyldithiocarbamate are the most effective compounds of those used in preventing blackening in *P. cecropia*. Although blackening of the blood usually accompanies death in these animals, these experiments have shown that such color changes are not a necessary part of the death process. The melanin reaction was inhibited in diseased as well as in healthy animals by the use of several copper chelaters and death was shown to occur despite the lack of pigmentation.

Analysis of the blood for the presence of phenols has shown that polyphenols begin to accumulate in the blood about one day after infection. Whether these compounds are produced by the fungus, or are merely products of the autolysis of animal protein has not been determined. It is probable, however, that the oxidation of the tryosine found in the blood of the normal animal accounts for much of the materials responding positively to the tests for polyphenols. That the presence of these phenols are one of the factors responsible for the death of the insect due to parasitism is suggested by the toxicity of some of these compounds for *P. cecropia* (Sussman 1952b).

Consequently, the reason for the death of *P. cecropia* due to this fungous disease can not be sought in the blackening process itself. Death is probably concerned with the accumulation of phenols which may either be produced by the fungus or by the insect itself. However, it must also be emphasized that the rapid overgrowth of the animal's tissues by the fungus, the subsequent removal of necessary food

materials, and the mechanical destruction of vital organs all play a part in the animal's death (Sussman 1952a).

SUMMARY

1. Sodium diethyldithiocarbamate and phenylthiourea have been found to be effective in preventing the blackening of the blood of the cecropia moth, *Platysamia cecropia*.

2. Blackening is shown not to be a necessary accompaniment of death in insects.

3. Although tyrosine is present in the normal insect's blood, polyphenols do not appear until one day after infection with *A. flavus*.

LITERATURE CITED

Bhagvat, K., and **Richter, D.** 1938. Animal phenolases and adrenaline. Bioch. Jour., 32: 1397–1406.

Feigl, F. 1937. Qualitative analysis by spot tests. Inorganic and Organic applications. Nordemann.

v. Furth, G., and **Schneider, H.** 1901. Ueber thierische Tyrosinase und ihre Beziehung zur Pigmentbildung. Hoff. Beitr. zur chem. Physiol. u. Path. 1: 229–252.

Heller, J. 1947. Metabolism of insect metamorphosis. Abstr. 17th intern. physiol. Cong. Oxford: 274–276.

Lison, L. Histochemie Animale. 1936. Gauthier-Villers. (Paris).

Schlottke, E. 1926. Über die Variabilität der schwarzen Pigmentierung und ihre Beeinflussbarkeit durch Temperaturen bei *Habrobracon juglandis* Ashmead. Ztschr. Vergl. Physiol. 3: 692–736.

Sussman, A. S. 1949. The functions of tyrosinase in insects. Quart. Rev. Biol. 24: 328–341.

1951a. Studies of an insect mycosis. I. Etiology of the disease. Mycologia, 43: 338–350.

1951b. Studies of an insect mycosis. II. Host and pathogen ranges. Mycologia, 43: 423–429.

1952a. Studies of an insect mycosis. III. Histopathology of the disease. Ann. Ent. Soc. Amer., 45: 233–245.

1952b. Tyrosinase and the respiration of pupae of *Platysamia cecropia*. Biol. Bull. 102: 39–47.

Vogel, A. I. 1948. A textbook of practical organic chemistry, including qualitative organic analysis. Longmans-Green.

Williams, C. M. 1946. Physiology of insect diapause: the role of the brain in the production and termination of pupal dormancy in the giant silkworm, *Platysamia cecropia*. Biol. Bull. 90: 234–243.

ERRATA

In vol. 45, no. 2, page 209, plate I, a "3" was erroneously inserted below fig. 6, in addition to the correct designation of that figure, and fig. 15, placed between figs. 13 and 14, was imperfectly designated.

SYSTEMATIC AND BIOLOGICAL STUDIES ON NORTH AMERICAN CHIGGERS OF THE GENUS TROMBICULA, SUBGENUS EUTROMBICULA

(Acarina, Trombiculidae)[1, 2]

KEITH A. WOLFENBARGER
University of Kansas, Lawrence

INTRODUCTION

The purpose of this paper is to give as completely as possible a systematic and biological report on the species of the subgenus *Eutrombicula* found in Kansas and surrounding states together with a systematic review of the North American species. In making the systematic study, about 5,000 specimens were examined and compared with specimens from other areas. Attempts were made to correlate larvae, nymphs, and adults by rearing in the laboratory and collecting in the field. The ecology, life history and time of maximum abundance were studied. As a result of these investigations the author recognizes three species in Kansas. One of these is a new species, one is a new state record, and one is a common chigger mite found throughout much of the Western Hemisphere.

In order to correlate this work with recent studies by other authors, particularly Jenkins (1949), a key is given to all known North American species of the subgenus *Eutrombicula*.

The terms used in describing leg segments and setae are those of Brennan and Wharton (1950). The use of these terms is indicated in fig. 1.

Slide numbers when used in the text or tables refer to the numbers given each specimen in the Snow Entomological Collections, University of Kansas.

ACKNOWLEDGMENTS

The studies upon which this paper is based were conducted in part under a contract, N6ori-220, Task Order 2, between the University of Kansas and the Office of Naval Research. Particularly useful were the excellent laboratory facilities and extensive chigger collections at the University of Kansas.

Thanks are extended to Mr. Richard B. Loomis of the University of Kansas for the collecting of chiggers and identification of hosts. Thanks are also due to Dr. George W. Wharton, Duke University, Dr. Willis J. Gertsch, American Museum of Natural History, and Mr. Douglas J. Gould, University of California, for the loan of speci-

[1]Contribution No. 776 from the Department of Entomology, University of Kansas, Lawrence.

[2]This paper was submitted to the Department of Entomology and the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of Master of Arts.

mens. Special acknowledgment is extended to Mr. Louis J. Lipovsky of the University of Kansas for the use of reared adult specimens, life history data on *Trombicula lipovskyana*, and many helpful suggestions.

For advice and criticism on the preparation of this paper, the author takes pleasure in extending thanks to Dr. Charles D. Michener of the Department of Entomology, University of Kansas. Dr. Dale W. Jenkins, Army Chemical Center, Maryland, and Dr. James M. Brennan, Rocky Mountain Laboratory, Hamilton, Montana, carefully reviewed this paper and gave many suggestions which were gratefully received.

Acknowledgment is due also to Miss Joanne Mannon for assistance in preparing the illustrations.

Subgenus **Eutrombicula** Ewing

Eutrombicula Ewing, 1938, Jour. Washington Acad. Sci., 28: 294.
Acariscus Ewing, 1943, Proc. Ent. Soc. Washington, 45: 57.

Oudemans (1910) described a chigger taken from man by Alfred Dugès in Mexico under the name *Microthrombidium alfreddugèsi*. Ewing (1938b) gave a description of his new genus, *Eutrombicula*, designating *alfreddugèsi* as its type, and later (1943) subdivided it further into the genus *Eutrombicula* and the genus *Acariscus*, basing his division on the number of abdominal setae. Michener (1946) refuted the use of *Acariscus*, considering it a synonym of *Eutrombicula*. This practice has been followed by more recent authors, including Jenkins (1949), who revised the species of *Eutrombicula* occurring in the Western Hemisphere.

I am following Jenkins and other recent students of chiggers in considering *Eutrombicula* s. str. as a subgenus of *Trombicula* instead of as a distinct genus.

Jenkins (1949) adequately described the subgenus *Eutrombicula* using both larval and adult characters. It should be noted the larvae of the recently described *T. belkini* have branched mastitarsalae on tarsus III, thus differing from Jenkins' description of the subgenus.

The following key to larvae of North American species is based upon that of Jenkins (1949). *T. tropica* (Ewing) is considered as a species rather than as a subspecies, since it appears to be found in the same habitat and on the same hosts as *T. alfreddugèsi*. It will require further study before its status can be definitely settled, but it does not appear from evidence at hand to be a subspecies of *T. alfreddugèsi*.

KEY TO NORTH AMERICAN TROMBICULA (EUTROMBICULA) LARVAE

A. Dorsal setae 32 to 54 in number; tibia III with two mastitibialae; tarsus III with three unbranched mastitarsalae.
  B. Dorsal setae 50 to 54, heavily barbed; ventral setae 42 to 46; pseudostigmatic setae with many short appressed branches..... **multisetosa**
  BB. Dorsal setae 36 to 38, lightly barbed; ventral setae 24; pseudostigmatic setae with 5 to 8 spreading branches..... **batatas**
AA. Dorsal setae 20 to 28; tibia III without mastitibialae; tarsus III with one unbranched mastitarsala or with two branched mastitarsalae.
  B. Tarsus III with two branched mastitarsalae (fig. 19); spur on tarsus I measuring 10 to 12 microns in length..... **belkini**
  BB. Tarsus III with one mastitarsala (fig. 16); spur on tarsus I measuring 13 to 33 microns in length.

C. Total dorsal and ventral setae 40 to 46; dorsal setae 24 to 28; ventral setae 16 to 17 ..... **splendens**
CC. Total dorsal and ventral setae 36; dorsal setae 22; ventral setae 14.
D. Palpal ventral tibial setae always branched; palpal genual setae usually branched.
E. Spur on tarsus I measuring 13 to 20 microns in length; palpal genual setae 18 to 21 microns in length; palpal claw with shallow cleft (figs. 10, 11) ..... **alfreddugèsi**
EE. Spur on tarsus I measuring 23 to 33 microns in length; palpal genual setae 24 to 33 microns in length; palpal claw with deep cleft (fig. 13) ..... **lipovskyana**
DD. Palpal ventral tibial and genual setae always nude. (Genual setae about 20 microns in length) ..... **tropica**

In making the following key, modified from that of Jenkins (1949), to known North American *Trombicula* (*Eutrombicula*) adults, the author found it difficult to separate *T. splendens* and *T. lipovskyana* in those individuals with nine apical nude setae on the palpal tarsus and two inner tibial setae at the tarsal articulation. This is important to note, since the larvae of *T. lipovskyana* resemble most nearly *T. alfreddugèsi*.

KEY TO KNOWN NORTH AMERICAN TROMBICULA (EUTROMBICULA) ADULTS

A. Palpal tarsus with 3 to 5 apical nude setae; eyes relatively large, diameter of eye 0.75 to 1.0 times distance between pseudostigmatic setae; scutum short (120–150 microns) ..... **batatas**
AA. Palpal tarsus with 6 to 11 apical nude setae; eyes smaller, diameter of eye 0.2 to 0.5 times distance between pseudostigmatic setae; scutum longer (131–199 microns).
B. Tarsus I long (220–277 microns); length of palpal claw 49–52 microns. (Width between pseudostigmatic setae 60–71 microns; inner tibial setae at tarsal articulation, usually one) ..... **lipovskyana**
BB. Tarsus I short (167–217 microns); length of palpal claw 35–48 microns.
C. Length of tarsus I 167–217 microns; width between pseudostigmatic setae 48–51 microns; palpal tarsus with 6–8 apical nude setae. **alfreddugèsi**
CC. Length of tarsus I 167–183 microns; width between pseudostigmatic setae 57–69 microns; palpal tarsus with 9–11 apical nude setae. . **splendens**

Trombicula (Eutrombicula) batatas (Linnaeus)

Acarus batatas Linnaeus, 1758, Syst. Nat., 10th Ed., Genus 235, Species 22.
Trombicula brasiliensis Ewing, 1925, Proc. Ent. Soc. Washington, 27: 92.
Trombicula flui van Thiel, 1930, Parasitology, 22: 347.
Trombicula pastorae Boshell and Kerr, 1942, Rev. Acad. Colombiana Cien. Exact., Fisico-Quim y Nat., 5: 12.
Acariscus hominus Ewing, 1943, Proc. Ent. Soc. Washington, 45: 63. For a complete synonymy *see* Jenkins (1949) and Fuller (in press).

Larva

Palpal claw as shown in fig. 6. Palpi with genual setae one- to three-branched, ventral tibial setae with one to five branches. Scutum as shown in fig. 21. Dorsal setae 36 to 38, ventral setae 24. Tibia III with one tibiala and two mastitibialae; tarsus III with three mastitarsalae as shown in fig. 20. Standard measurements as shown in Tables I and III.

T. batatas has previously been described as having from 32 to 36 dorsal setae and 22 ventral setae. It is evident, however, from a study of specimens from Panama (recorded as *batatas* by Michener, 1946b)

in the American Museum of Natural History and other specimens collected in Kansas that *T. batatas* has from 36 to 38 dorsal setae and 24 ventral setae. In counting the dorsal and ventral setae, humeral, posterior caudal, marginal, and sternal setae are included. On a few specimens setae are missing, which gives an asymmetrical arrangement while in others dorsal setae move into preceeding rows so that the dorsal setal formula varies. A single specimen (slide number 235, collected by Louis J. Lipovsky and Richard B. Loomis from a western meadowlark, *Sturnella neglecta*, field number RL 480909–11, 12 miles north east of Liberal, Seward County, Kansas) agrees with *T. batatas* except for having a total count of 74 dorsal and ventral setae.

Adult[3]

Body length 0.7 to 1.0 mm. Palpal tarsus with three to five stout, nude apical setae; one inner tibial setae at tarsal articulation. Width between pseudostigmatic setae 38 to 47 microns; pseudostigmatic setae 131 to 143 microns in length. Diameter of eye 0.75 to 1.0 times the distance between the pseudostigmatic setae. Tarsus I about 190 microns in length. Longest posterior body setae 36 to 40 microns in length; longest humeral setae about 31 microns.

Ecology and distribution in Kansas.—In examining larvae from a kangaroo rat, *Dipodomys ordii*, field number RL 480909–15, slide numbers 231–242, 259, 408, and from a western meadowlark, *Sturnella neglecta*, field number RL 480909–11, slide number 225, collected twelve miles northeast of Liberal, Seward County, Kansas, September 9, 1948, by Richard B. Loomis and Louis J. Lipovsky, several specimens of *T. batatas* were identified. Except as indicated above, all specimens were found to be identical with *T. batatas* as shown in fig. 2. This appears to be the first record of *T. batatas* in Kansas, all previously published records in North America being from Mexico, Florida, Alabama, Georgia, and California (Jenkins, 1949).

The *T. batatas* larvae recorded from Kansas were taken from two typical prairie inhabitants in the sagebrush-covered sandy valley of the Cimarron River. The locality, however, was near the river bank, a situation found favorable for this species in Panama (see Michener, 1946a).

Trombicula (Eutrombicula) belkini Gould

Trombicula (Eutrombicula) belkini Gould, 1950, Wasman Jour. Biol., 8: 367.

Larva

Palpal claw as shown in fig. 15. Palpi with genual setae one-branched. Ventral tibial setae with three branches, femoral setae with five to six-branches. Scutum as shown in fig. 25. Dorsal setae 22, ventral setae 14. Spur on tarsus I measuring from 10 to 12 microns in length. Tibia III with one tibiala; tarsus III with two branched mastitarsalae as shown in fig. 19. Standard measurements as shown in Tables I and IV.

[3]After Jenkins (1949)

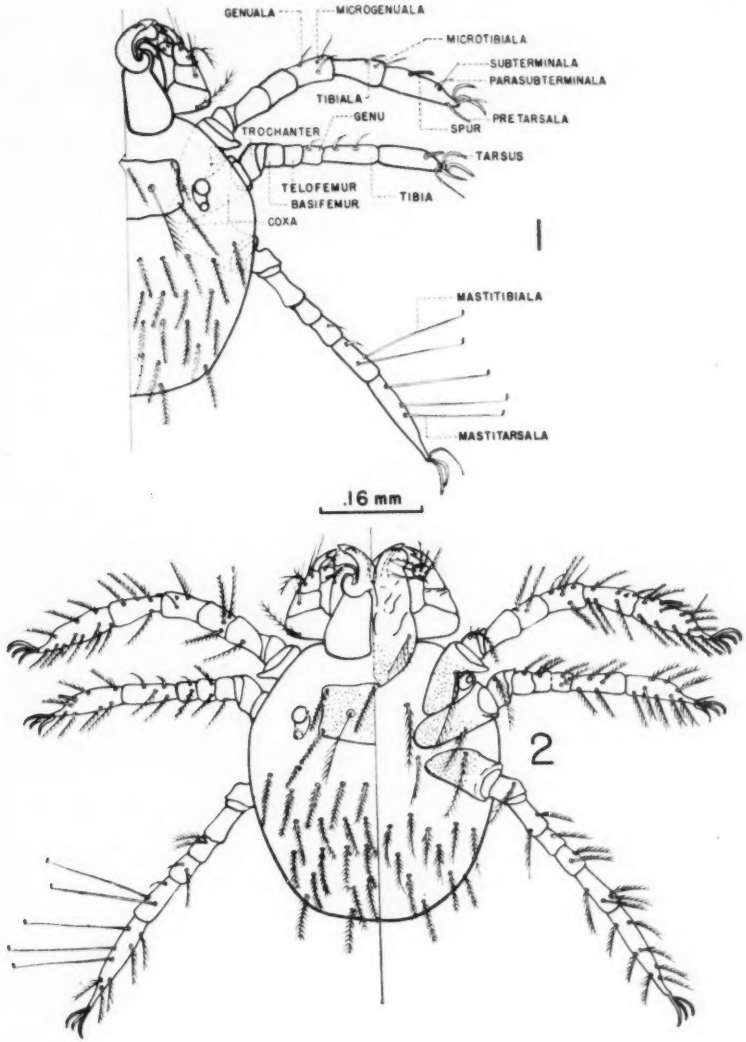


FIG. 1. Larva of *T. batatas*, dorsal view of right half with structures labeled.
FIG. 2. Larva of *T. batatas*, dorsal view on left, ventral view on right.

Distribution.—The author has examined larvae of *T. belkini* collected by Douglas J. Gould at Palos Verdes Estates, Los Angeles County, California, on the following dates and hosts:

Slide numbers 2045–2053, taken from lawn, August 31, 1949.
Slide number 2054, taken from *Mus musculus*, September 2, 1949.
Slide number 2055, taken from *Perognathus californicus*, August 31, 1949.
Slide number 2056, taken from *Reithrodontomys megalotis*, September 2, 1949.

Trombicula (Eutrombicula) splendens Ewing

Trombicula splendens Ewing, 1913, Bull. Amer. Mus. Nat. Hist., 32: 113.
Trombiculoides scabrum Jacot, 1938 (*nec* Say, 1821), Psyche, 45: 123.
Acariscus masoni Ewing, 1943, Proc. Ent. Soc. Washington, 45: 60.
For a complete synonymy see Jenkins (1949).

Larva

Palpal claw as shown in fig. 8. Palpi with genual setae simple to three-branched, ventral tibial setae with two to five branches, femoral setae simple to six-branched. Scutum as shown in fig. 22. Dorsal setae 24 to 28, ventral setae 16 to 17. Tibia III with one tibiala; tarsus III with one mastitarsala as shown in fig. 16. Standard measurements as shown in Tables I and V.

Adult[4]

Body length 0.9 to 1.4 mm. Palpal tarsus with nine to eleven stout, nude apical setae; usually two inner tibial setae at tarsal articulation. Width between pseudostigmatic setae 57 to 69 microns; pseudostigmatic setae 167 to 179 microns in length. Diameter of eye 0.3 to 0.5 times the distance between the pseudostigmatic setae. Tarsus I from 167 to 183 microns in length. Longest posterior body setae 48 to 76 microns in length; longest humeral setae 31 to 43 microns in length.

Distribution.—This species has been reported from Kansas by Ewing (1921), and may be expected to occur in the eastern part of the state for it is known from eastern Texas to Minnesota and eastward to the Atlantic. Specimens in the Snow Entomological Collections were obtained as indicated below:

Larvae of *T. splendens* were collected from the following hosts in the following places:

Thamnophis sirtalis, common garter snake, field number F4709050–1, slide numbers 480–481, 483–494, 496–499, collected by L. J. Lipovsky and R. B. Finley, one and one-half miles east of Aurora, Lawrence County, Missouri, September 5, 1947.

Pipilo erythrophthalmus, towhee, field number F470905–7, slide numbers 482 and 495, collected by L. J. Lipovsky and R. B. Finley, one and one-half miles east of Aurora, Lawrence County, Missouri, September 5, 1947.

T. splendens larvae, slide numbers 409–414, 416–441, were reared from adults collected under the bark of decaying trees, by L. J. Lipovsky, three miles northwest of Talco, Red River County, Texas, March 26, 1948.

[4]After Jenkins (1949).

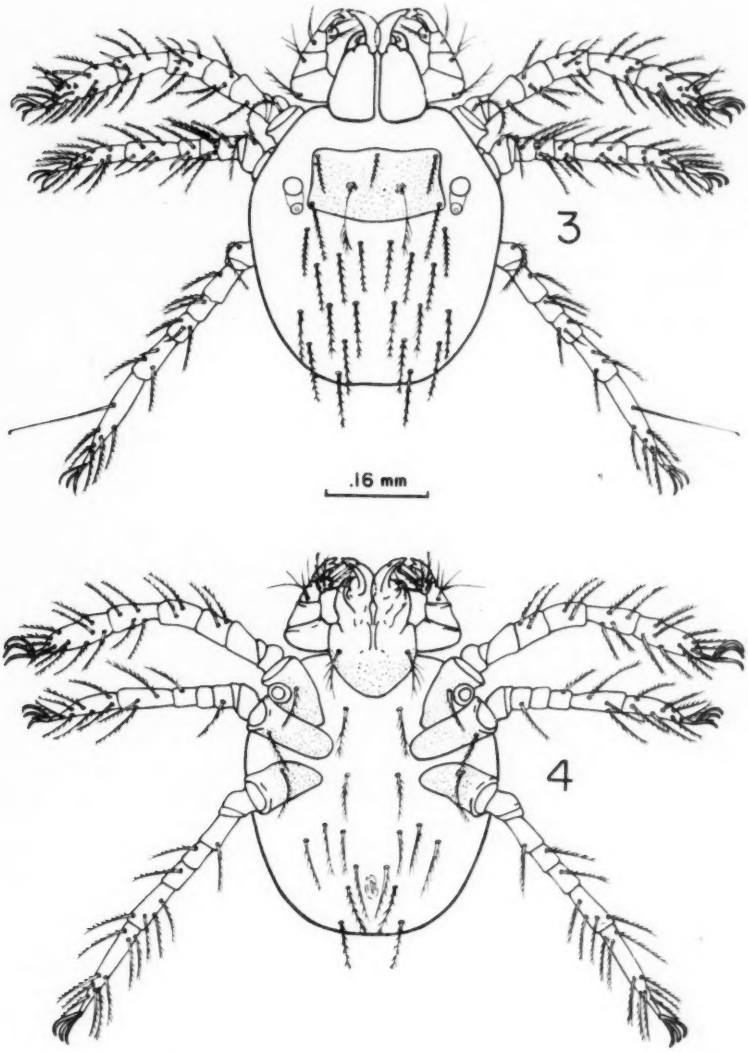


FIG. 3. Larva of *T. lipovskyana*, dorsal view. FIG. 4. Larva of *T. lipovskyana*, ventral view.

Trombicula (Eutrombicula) alfreddugèsi (Oudemans)

Leptus irritans Riley, 1873, Amer. Nat., 7: 18.
Tetranychus tlalsahuate Murray, 1877, Econ. Ent., South Kensington Museum Sci. Handb., p. 113.
Microthrombidium alfreddugèsi Oudemans, 1910, Ent. Ber., 3(54): 84.
Microthrombidium tlalzahuatl Oudemans, 1912, Zool. Jahrb. (Suppl.), 14: 18.
Trombicula cinnebaris Ewing, 1921, Ann. Ent. Soc. Amer., 13: 387.
Leptus similis Hirst, 1921, Ann. Mag. Nat. Hist., (9)7: 37.
Leptus rileyi Oudemans, 1939, Zool. Anz., 127: 80.
Trombicula irritans var. *uruguayensis* Andrè, 1930, Ann. Parasitol. Hum & Comp., 8: 356.
Trombicula vanommereni Schierbeek, 1937, Ann. Parasitol. Hum. & Comp., 15(4): 326.
Trombicula butantanensis De Fonseca, 1932, Mem. Inst. Butantan, 7(5): 147.

For a complete synonymy see Jenkins (1949) and Fuller (in press). For validity of the present name see Ewing, 1938a, Proc. Helm. Soc. Washington, 5: 26–27.

Larva

Palpal claw as shown in figs. 10 and 11. Palpi with genual setae simple to four-branched, ventral tibial setae simple to five-branched. Scutum as shown in fig. 23. Dorsal setae 22, ventral setae 14. Spur on tarsus I measuring from 13 to 20 microns in length as shown in Plate VIII. Tibia III with one tibiala; tarsus III with one mastitarsala as shown in fig. 17. Standard measurements as shown in Tables I and VI.

Nymph

The eight legged nymph closely resembles the adult.

Body.—Elongate with posterior end evenly rounded; anterior dorsal margins evenly rounded; entire body densely covered with plumose hairs of varying lengths. Dorsal and lateral constrictions slightly anterior to the middle giving a figure-eight or hour-glass appearance. Length 0.4 to 0.5 mm., width 0.28 to 0.35 mm. Color moderate to brilliant red.

Gnathosoma.—Palpus with few setae. Tibia with two blunt, stout, inner distal setae; a longer, sharp, stout, three-branched, median dorsal seta; one seta on inner surface at tarsal articulation; and a claw at apex. Base of claw produced ventrally to a sharp point; length of claw 0.6 to 0.8 times length of tibia. Tarsus with many branched setae and with five simple, short, curved, apical setae. Chelicerae sword-shaped with dorsal margin serrate (fig. 29).

Legs.—Four pairs of segmented legs, the anterior pair being longest with enlarged tibia and tarsus. Length of tarsus I, 0.48 to 0.6 times its width, and 1.2 to 1.9 times length of tibia I (Table VI). Coxa I and II contiguous, forming a plate anteriorly and coxae III and IV contiguous forming a plate posteriorly at the body constriction. Legs covered with many stout, nude and branched setae. Tarsi with two claws each.

Scutum.—Length 83 to 95 microns measuring from anterior end of crista to posterior lobes of dorsal saddle. Crista slender and tube-like; pseudostigmatic area broadened with a dorsal saddle extending anteriorly and laterally to the posterior margin of the pseudostigma, and

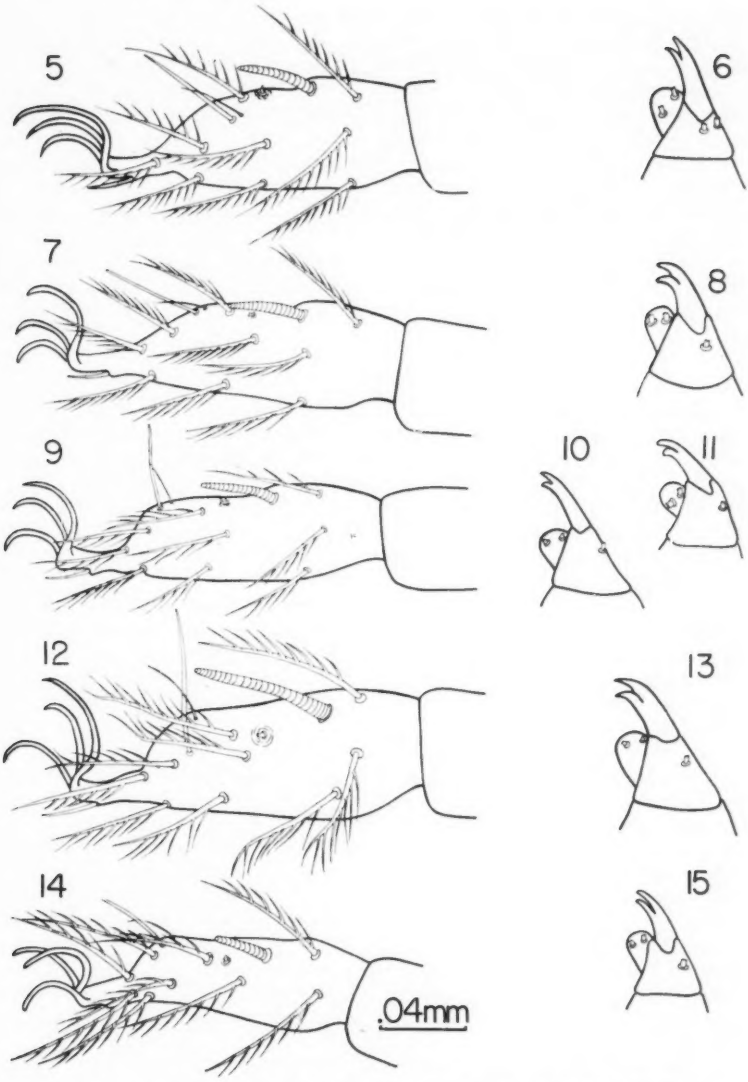


FIG. 5. Tarsus I of *T. batatas* larva. FIG. 6. Palpal claw of *T. batatas* larva. FIG. 7. Tarsus I of *T. splendens* larva. FIG. 8. Palpal claw of *T. splendens* larva. FIG. 9. Tarsus I of *T. alfreddugèsi* larva. FIGS 10 and 11. Palpal claws of *T. alfreddugèsi* larvae, showing extremes of variation. FIG. 12. Tarsus I of *T. lipovskyana* larva. FIG. 13. Palpal claw of *T. lipovskyana* larva. FIG. 14. Tarsus I of *T. belkini* larva. FIG. 15. Palpal claw of *T. belkini* larva.

extending posteriorly into a biconvex margin with two lateral lobes. Each pseudostigma bearing a distally four to five-branched pseudostigmatic seta measuring 99 to 106 microns in length; width between pseudostigmatic setae 32 to 39 microns (fig. 28). Convex eyes posterolateral of each pseudostigma measuring 0.29 to 0.30 times the distance between the pseudostigmatic setae.

Setae.—Body setae heavily branched and red in color, arising from disc-like, medially raised papillae (fig. 32). Longest humeral setae slightly shorter than longest posterior setae, which measures 41 to 49 microns in length (Table VII).

Genitalia.—Located medially on the ventral surface, posterior to coxae IV. Males and females are indistinguishable, both sexes having four rounded genital suckers. Posterior to the genital area is an oval anus.

Adult

Body length 0.8 to 1.1 mm. Palpal tarsus with six to eight stout, nude apical setae; usually two inner tibial setae (occasionally, one or three) at tarsal articulation (fig. 33). Width between pseudostigmatic setae 44 to 52 microns; pseudostigmatic setae 143 to 177 microns in length (fig. 27). Diameter of eye 0.3 to 0.5 times distance between the pseudostigmatic setae. Tarsus I, 167 to 217 microns in length. Longest posterior body setae 42 to 69 microns in length (fig. 31); longest humeral setae 30 to 48 microns in length (Table VIII).

Life history.—Larvae were collected from a collard lizard, *Crotaphytus collaris* living in an area which, over a two year period of larval sampling, proved to have a pure population of *T. alfreddugèsi*. *Crotaphytus* was chosen as a host because it has a small home range in this locality, is small in size, requires little food, is harmless to handle and excretes little.

Allowing the engorged larvae to drop directly into a half pint mason jar, the inside of which was lined with a mixture of plaster of Paris and charcoal, required little handling and afforded large numbers of uninjured larvae for culturing. Table IX gives a summary of the stages in the life history of *T. alfreddugèsi*. Terminology used follows Michener (1946b) with the exception of the term prenympha introduced here to replace the term protonymph (nymphochrysalis of other authors). The term prenympha seems preferrable to nymphochrysalis, being less cumbersome, and to protonymph, a term used elsewhere among the mites for the first of two or more nymphal stages. The room temperature was maintained at approximately 80° F. and the relative humidity in the cultures was near the saturation point throughout the life cycle.

Seasonal activity.—*T. alfreddugèsi* was found to be the most abundant species of the subgenus *Eutrombicula* in Kansas. The larvae are very bad pests, causing severe cases of trombiculosis during the months of June, July, August and September. Larvae appear late in May, gradually building up to a peak abundance in late June and early July, after which time they gradually decrease in numbers disappearing during late October.

Ecological and geographic distribution in Kansas and surrounding areas.—*T. alfreddugèsi* larvae appear to be able to thrive in every

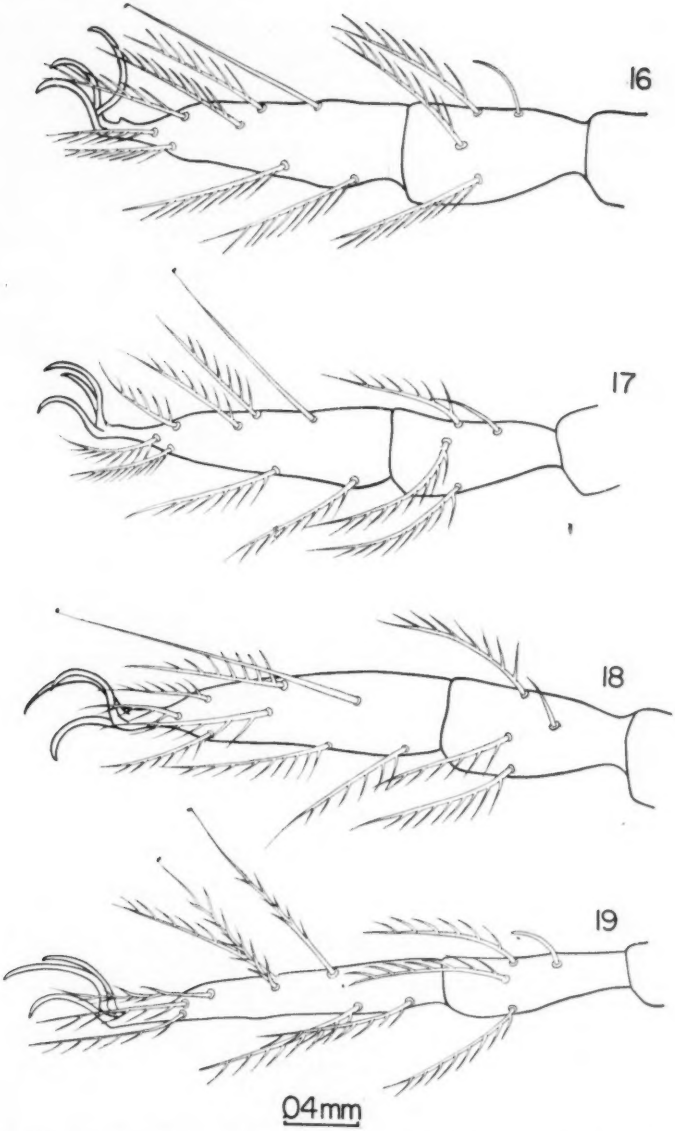


FIG. 16. Tarsus III of *T. splendens* larva. FIG. 17. Tarsus III of *T. alfred-dugèsi* larva. FIG. 18. Tarsus III of *T. lipovskyana* larva. FIG. 19. Tarsus III of *T. belkini* larva.

region of Kansas. Larvae have been collected on hot, arid plains and in low, moist river valleys under both conditions of drought and excessive rain. Below is a list of hosts and counties from which larvae have been collected:

ARKANSAS:
- Crawford County:
  - Lizard:
    - *Sceloporus undulatus* (1)[5]
- Newton County:
  - Lizard:
    - *Sceloporus undulatus* (28)
- Pope County:
  - Bird:
    - *Thryothorus ludovicianus* (1)
- Washington County:
  - Birds:
    - *Thryothorus ludovicianus* (14)
    - *Toxostoma rufum* (4)

COLORADO:
- Boulder County:
  - Mammal:
    - *Peromyscus maniculatus* (1)
- Dolores County:
  - Lizard:
    - *Urosaurus ornatus wrighti* (1)
- La Plata County:
  - Mammal:
    - *Neotoma albigula laplataensis* (1)

KANSAS—EASTERN:
- Cloud, Shawnee, Jefferson, Leavenworth, Douglas, Miami, Montgomery, and Anderson Counties:
  - Lizards:
    - *Cnemidophorus sexlineatus* (1)
    - *Crotaphytus collaris* (30)
    - *Eumeces obsoletus* (37)
  - Snakes:
    - *Agkistrodon contortrix mokeson* (2)
    - *Crotalus horridus* (2)
    - *Elaphe obsoleta* (15)
    - *Lampropeltis calligaster* (10)
    - *Lampropeltis getulus holbrooki* (8)
    - *Pituophis catenifer sayi* (67)
    - *Thamnophis sirtalis parietalis* (73)
  - Turtle:
    - *Terrapene ornata* (7)
  - Birds:
    - *Agelaius phoeniceus* (15)
    - *Bartramia longicauda* (11)
    - *Chondestes grammacus* (3)
    - *Colinus virginianus* (15)
    - *Corvus brachyrhynchos* (8)
    - *Cyanocitta cristata* (2)
    - *Icterus galbula* (1)
    - *Molothrus ater* (5)
    - *Parus bicolor* (1)
    - *Passer domesticus* (22)
    - *Pipilo erythrophthalmus* (1)
    - *Piranga rubra* (2)
    - *Quiscalus quiscula* (41)
    - *Rallus* (4)
    - *Richmondena cardinalis* (102)
    - *Sialia sialis* (3)
    - *Spiza americana* (42)
    - *Spizella passerina* (1)
    - *Sturnella magna* (2)
    - *Sturnus vulgaris* (1)
    - *Troglodytes aedon* (4)
    - *Turdus migratorius* (16)
    - *Zenaidura macroura* (28)
  - Mammals:
    - *Canis familiaris* (1)
    - *Cryptotis parva* (6)
    - *Microtus ochrogaster* (4)
    - *Neotoma floridana* (14)
    - *Peromyscus leucopus* (1)
    - *Reithrodontomys megalotis* (1)
    - *Sciurus niger* (9)
    - *Sigmodon hispidus* (102)
    - *Sylvilagus floridanus* (102)

KANSAS—WESTERN:
- Cheyenne, Rawlins, Wallace, Seward, and Barber Counties:
  - Lizards:
    - *Cnemidophorus sexlineatus* (1)
    - *Eumeces obsoletus* (23)
    - *Sceloporus undulatus garmani* (37)
  - Snakes:
    - *Coluber constrictor flaviventris* (4)
    - *Heterodon nasicus* (17)
    - *Masticophis flagellum testaceus* (116)
    - *Natrix erythrogaster* (5)
    - *Pituophis catenifer sayi* (24)
    - *Thamnophis radix* (1)
    - *Thamnophis sauritus proximus* (8)
  - Turtle:
    - *Terrapene ornata* (50)
  - Birds:
    - *Calamospiza melanocorys* (1)
    - *Colinus virginianus* (10)
    - *Eremophila alpestris* (6)
    - *Sturnella neglecta* (11)
  - Mammals:
    - *Citellus tridecemlineatus* (1)
    - *Dipodomys ordii* (5)
    - *Mus musculus* (11)
    - *Neotoma micropus* (15)
    - *Onychomys leucogaster* (3)
    - *Perognathus hispidus* (24)
    - *Peromyscus maniculatus* (7)
    - *Rattus norvegicus* (6)
    - *Reithrodontomys megalotis* (10)
    - *Sigmodon hispidus* (116)
    - *Sylvilagus floridanus* (10)

[5]Figures in parentheses indicate number of specimens of chiggers examined.

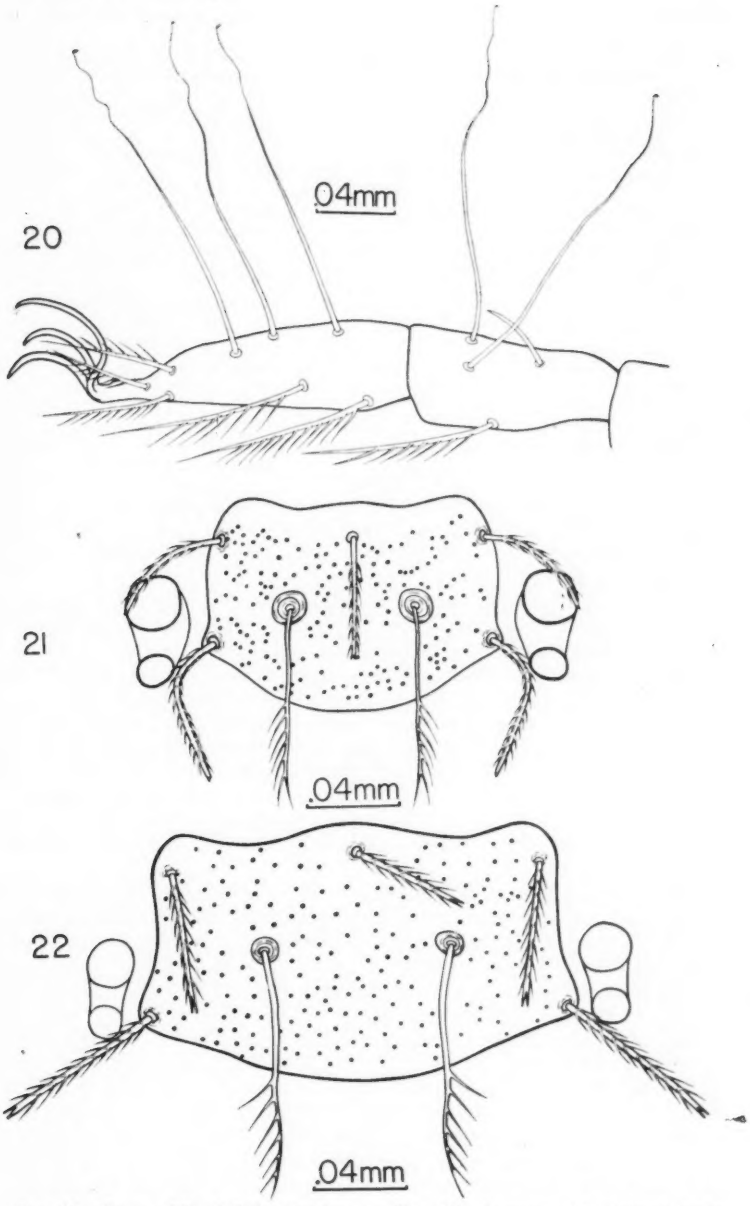


FIG. 20. Tarsus III of *T. batatas* larva. FIG. 21. Scutum of *T. batatas* larva.
FIG. 22. Scutum of *T. splendens* larva.

MISSOURI:
Jasper County:
Snake:
Thamnophis sirtalis sirtalis (12)
Lawrence County:
Lizard:
Sceloporus undulatus (2)
Snake:
Thamnophis sirtalis sirtalis (24)
Bird:
Pipilo erythrophthalmus (1)
Mammals:
Peromyscus leucopus (1)
Reithrodontomys fulvescens (1)
Taney County:
Snake:
Coluber constrictor (8)
Bird:
Spizella pusilla (1)
Mammal:
Sigmodon hispidus (8)
NEBRASKA:
Dundy County:
Snake:
Pituophis catenifer sayi (9)
Richardson County:
Amphibian:
Bufo woodhousii (1)
Snake:
Pituophis catenifer sayi (5)
Mammal:
Pitymys nemoralis (1)
OKLAHOMA:
Delaware County:
Lizards:
Eumeces fasciatus (1)
Sceloporus undulatus hyacinthinus (10)
Bird:
Richmondena cardinalis (4)
Mammals:
Didelphis virginiana (15)
Sigmodon hispidus (1)
Woods County:
Snake:
Sonora episcopa (1)
Mammal:
Tadarida mexicana (3)

During the summer months nymphs and adults were collected under rocks in wooded areas immediately after rains, and on warm sunny days, in open pastures a few inches beneath the soil surface in cracks and crevices made by grass roots.

Method of collecting nymphs and adults.—The author found the floatation method used by Cockings (1948) the most convenient way to collect large numbers of adults.

For collecting adults, locations were chosen where larval counts were high. Within such an area a four inch cube of sod was removed intact and placed upside down in a flat bottomed metal pan filled with five gallons of water. The sod was then broken apart and thoroughly saturated allowing adults to break free and float to the surface. Adults were then removed from the surface with a camels hair brush and placed in tubes filled with a mixture of plaster of Paris and charcoal. In these tubes they were easily carried in the field and later transferred to culture dishes.

Geographical variation in larvae.—The author has found that there are a number of larval characters which show geographic variation. As an example, the length of the spur on tarsus I of *T. alfreddugèsi* has been studied in detail. The length of this spur falls within a range of 13 to 20 microns. In examining larvae from different populations the mean varied only slightly (see Plate VIII). The mode however varied more, with specimens from North Carolina having shorter spurs in general as indicated in Plate VIII. The cleft of the palpal claw of *T. alfreddugèsi* varies considerably in depth. Samples of Western Kansas populations contain more individuals with deeper clefts than those from Eastern Kansas. Therefore, it is necessary, in examining populations, to study a large enough series of specimens to guard against mistaken identification due to studying only extremes of variation.

It is very probable that various populations will later be defined as subspecies; however, the results of this study do not warrant such a separation.

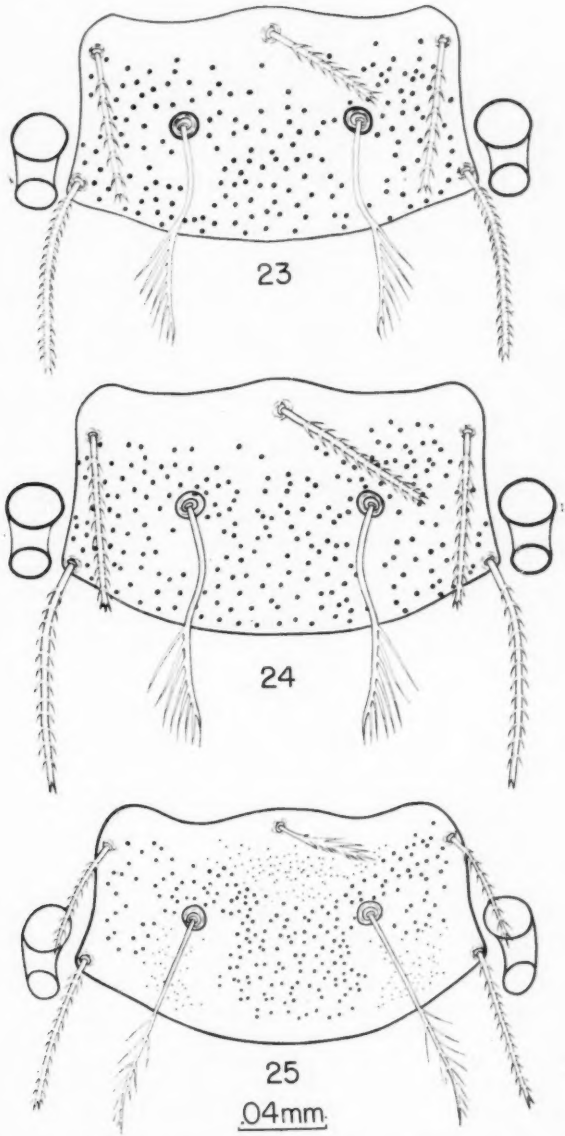


FIG. 23. Scutum of *T. alfreddugèsi* larva. FIG. 24. Scutum of *T. lipovskyana* larva. FIG. 25. Scutum of *T. belkini* larva.

Trombicula (Eutrombicula) lipovskyana, new species
(Figs. 3, 4, 12, 13, 18, and 24)

Larva

Body.—Length and width of unengorged holotype, 248 by 234 microns. Body shape and size similar to *T. splendens* and *T. alfreddugèsi.*

Gnathosoma.—Palpal claw thick and deeply cleft as shown in fig. 13. Setal number and position as in other *Eutrombicula* (figs. 3 and 4). Palpus with genual seta simple to three-branched, ventral tibial seta with one to four branches.

Scutum.—Essentially as in *T. splendens*, shown in fig. 24. Setae long. Standard measurements as shown in Table X.

Legs.—Setal number and position as shown in figs. 3 and 4. Spur on tarsus I, 23 to 33 microns in length as shown in Plate VIII. Tibia III with one tibiala; tarsus III with one mastitarsala as shown in fig. 18.

Body setae.—Dorsal setae 22, ventral setae 14; arrangement shown in fig. 3 and 4.

Diagnosis.—*T. lipovskyana* is similar to *T. alfreddugèsi* and *T. splendens* in most characters, but differs from both in the greater length of the spur on tarsus I measuring 23 to 33 microns as compared to 13 to 20 microns. Dorsal and ventral setae total 36 as with *T. alfreddugèsi*, 40 to 46 in *T. splendens*. The scutal plate more nearly resembles *T. splendens* in size and shape. Length of scutal and body setae, in general, appear longer than *T. alfreddugèsi*, approximately the same length as in *T. splendens*. PL averages 50 microns in *T. lipovskyana*, 40 microns in *T. alfreddugèsi* (from Kansas), and 52 microns in *T. splendens* (from Missouri). Palpal claw is thicker and more deeply cleft than in *T. alfreddugèsi*, being similar to *T. splendens* (figs. 8, 10, 11 and 13).

Nymph

While examining nymphs reared from engorged larvae taken at the type locality of *T. lipovskyana*, one (slide number 743), reared fram larvae taken from *Colinus virginianus*, bobwhite quail, field number L480725–3 to 6, collected by L. J. Lipovsky, July 25, 1948, and two (slide numbers 742, 454), reared from larvae taken from *Zenaidura macroura*, mourning dove, field number L480725–7 collected by L. J. Lipovsky, July 25, 1948, the author found nymphs quite different from those of *T. alfreddugèsi*. Since larvae could not be reared from them, there is not absolute evidence of their being *T. lipovskyana*, but they probably represent this species. The following is a description:

Body.—Elongate, with posterior end evenly rounded; anterior dorsal margins evenly rounded; entire body densely covered with plumose hairs of varying lengths. Dorsal and lateral constrictions slightly anterior to the middle giving a figure-eight or hour glass appearance. Length 0.8 to 0.85 mm.; width 0.74 mm. Color moderate to brilliant red.

Gnathasoma.—Palpus with few setae. Tibia with two blunt, stout, inner distal setae; a longer sharp, stout three-branched, median dorsal seta; one seta on inner surface at tarsal articulation; and claw at apex. Base of claw produced ventrally to a sharp point; length of claw 0.6 to 0.7 times length of tibia. Tarsus with many branched setae and with five simple, short, curved, apical setae. Chelicerae sword-shaped with dorsal margin serrate.

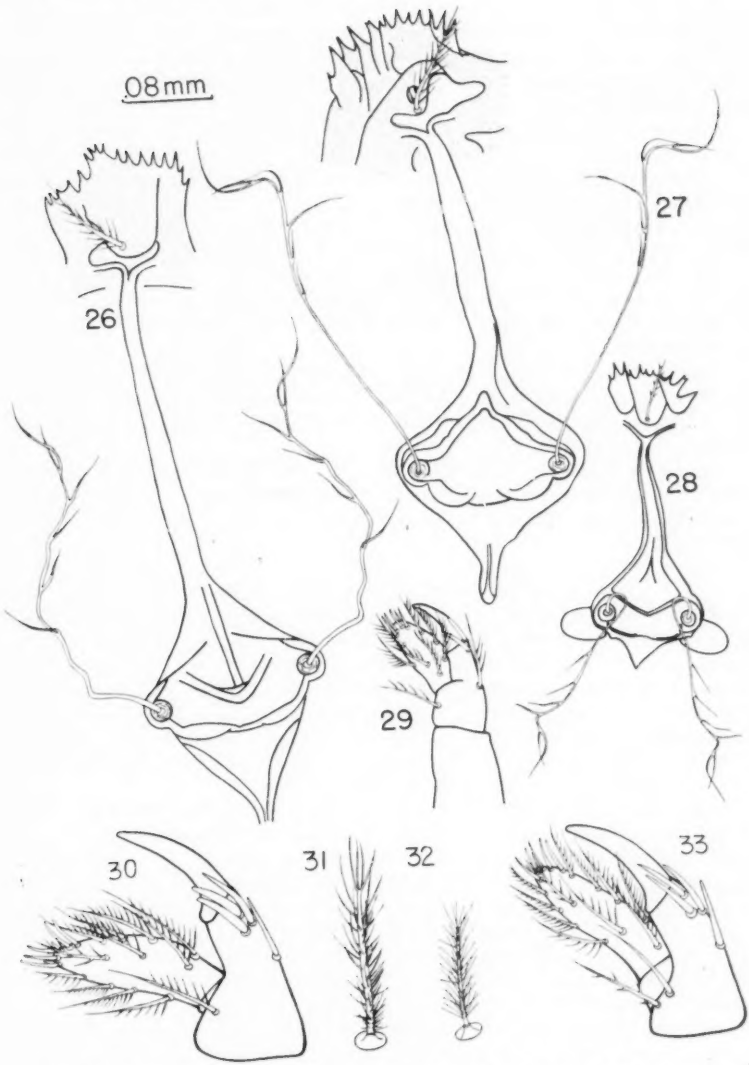


FIG. 26. Scutum of *T. lipovskyana* adult. FIG. 27. Scutum of *T. alfreddugèsi* adult. FIG. 28. Scutum of *T. alfreddugèsi* nymph. FIG. 29. Inner distal view of palp of *T. alfreddugèsi* nymph. FIG. 30. Inner distal view of palp of *T. lipovskyana* adult. FIG. 31. Posterior hair of *T. alfreddugèsi* adult. FIG. 32. Posterior hair of *T. alfreddugèsi* nymph. FIG. 33. Inner distal view of palp of *T. alfreddugèsi* adult.

Legs.—Four pairs of segmented legs, the anterior pair being longest with enlarged tibia and tarsus. Length of tarsus I, 0.46 to 0.51 times its width, and 0.69 times length of tibia I. Coxa I and II contiguous forming a plate posteriorly at the body constriction. Legs covered with many stout nude and branched setae. Tarsi with two claws each.

Scutum.—Length 114 to 158 microns measuring from anterior end of crista to posterior lobes of dorsal saddle. Crista slender and tube-like; pseudostigmatic area broadened with a dorsal saddle extending anteriorly and laterally to the posterior margin of the pseudostigma, and extending posteriorly into a biconvex margin with two lateral lobes. Each pseudostigma bearing a distally five-branched pseudostigmatic seta measuring 131 to 142 microns in length; width between pseudostigmatic setae 46 to 48 microns. Convex eyes posterolateral of each pseudostigma measuring 0.3 times the distance between the pseudostigmatic setae.

Setae.—Body setae heavily branched and red in color arising from disc-like, medially raised papillae. Longest humeral setae slightly shorter than longest posterior setae, which measures 58 to 62 microns in length (Table XI).

Genitalia.—Located medially on the ventral surface, posterior to coxae IV. Males and females are indistinguishable, both sexes having four rounded genital suckers. Posterior to the genital area is an oval anus.

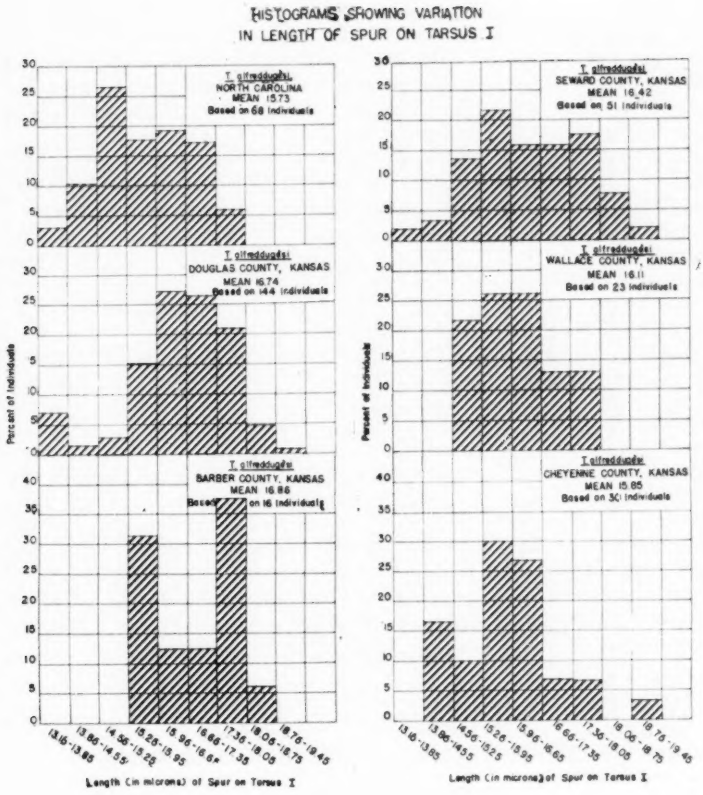
Adult

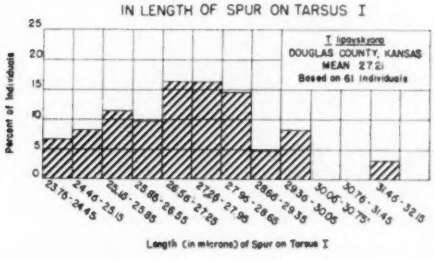
Body length 0.9 to 1.8 mm. Palpal tarsus with seven to nine stout, nude apical setae; usually one (occasionally two) inner tibial seta at tarsal articulation (fig. 30). Width between pseudostigmatic setae 61 to 71 microns; pseudostigmatic setae 148 to 204 microns in length (fig. 26). Diameter of eye 0.21 to 0.33 times distance between the pseudostigmatic setae. Tarsus I 220 to 277 microns in length. Longest posterior body setae 60 to 71 microns in length; longest humeral setae 42 to 57 microns in length (Table XII).

Life history.—Engorged larvae (slide numbers 394–404) were taken from four bobwhite quail, *Colinus virginianus*, field number L480725–3 to 6, collected four miles south of Lawrence, Douglas County, Kansas, July 25, 1948, and placed in a culture dish. Records were not kept until after the adults reared from the above larvae, began laying eggs. Fifteen adults were preserved from the culture, eleven of which were male and female *T. lipovskyana* and four female *T. alfreddugèsi*. All larvae from this culture, until later contamination with *T. alfreddugèsi* were *T. lipovskyana*.

In this culture it was observed *T. lipovskyana* completed its life cycle from detached engorged larvae to unengorged larvae of the next generation in approximately 170 days with the egg stage taking approximately 30 days. From these preliminary data *T. lipovskyana* apparently takes a greater length of time than *T. alfreddugèsi* to complete its life cycle.

The culture was maintained under variable temperature and humidity, quite contrary to the more constant temperature and humidity under which *T. alfreddugèsi* was reared in approximately 71 days from detached engorged larvae to unengorged larvae.





Histograms showing variation in length of spur on tarsus I of *T. alfreddugèsi* and *T. lipovskyana* larvae.

It is possible no males of *T. alfreddugèsi* were present in the culture; this might explain its failure to produce larval *T. alfreddugèsi* in spite of the presence of a few females of this species.

Seasonal activity.—In 1950 larvae of *T. lipovskyana* began to appear around June 12, increasing in numbers during July and August, after which time they gradually decreased in numbers, disappearing completely about October 25.

Ecological and geographic distribution in Kansas and surrounding areas.—*T. lipovskyana* larvae have been collected in several places throughout Kansas and in Arkansas. *T. lipovskyana* seems to be restricted to moist areas near streams and swamps and unlike *T. alfreddugèsi* was never found in pure populations. *T. alfreddugèsi* was always found in the same habitat with *T. lipovskyana*, and was often found on the same hosts. Below is a list of hosts and localities from which they have been collected.

Type data.—*Holotype*, field number L480725–3, 6, slide number 404, in the Snow Entomological Collections, University of Kansas, Lawrence. Paratypes will be deposited in the United States National Museum; Rocky Mountain Laboratory, United States Public Health Service; and Duke University. Holotype and eleven paratypic larvae, slide numbers 394–403, taken from *Colinus virginianus*, field number L480725–3, 6, collected four miles south of Lawrence, Douglas County, Kansas, July 25, 1948, by Louis J. Lipovsky; twelve additional paratypic larvae, slide numbers 41–48, 60–63, taken from *Passer domesticus*, field number L480715–1, on the University of Kansas campus, Lawrence, Douglas County, Kansas, July 15, 1948 by Louis J. Lipovsky. For measurements of paratypes see Table X. Most of the specimens listed below are not designated as paratypes.

ARKANSAS:
Pope County:
Birds:
Parus carolinensis[6]
F470909–5[7]; Piney[8]; September 9, 1947[9]; 217, 218, 730–734.[10]
Washington County:
Bird:
Toxostoma rufum
F470910–1; Fayetteville; September 10, 1947; 737–740.

KANSAS:
Anderson County:
Lizard:
Crotaphytus collaris
RL490717–8; two miles north of Garnett; July 17, 1949; 678–683.
Bourbon County:
Bird:
Richmondena cardinalis
F470903–15; one mile west of Ft. Scott; September 3, 1947; 684–693.
Cheyenne County:
Mammal:
Mus musculus
RL480722–4; St. Francis' Dump; July 22, 1948; 307–312.
Douglas County:
Lizard:
Eumeces obsoletus
L470729–10; Lawrence; July 29, 1947; 671, 672.

[6]Host. [7]Field number of host. [8]Locality data. [9]Date collected. [10]Slide numbers (Snow Entomological Collections).

Snakes:
Crotalus horridus
F470819–1; five miles north, one mile east of Lawrence; Aug. 19, 1947; 2001.
Thamnophis sirtalis parietalis
L470816–4; three miles north, one mile east of Lawrence; August 16, 1947; 673–675.
Birds:
Agelaius phoeniceus
F471024–1, 2; two miles south, one-half mile east of Lawrence; October 24, 1947; 500–505.
RL480713–2; seven miles southeast of Lawrence; July 13, 1948; 140, 142, 143, 146, 151.
RL480713–2; seven miles to two miles southeast of Lawrence; July 14, 1948; 156, 506.
Bartramia longicauda
RL480714–5; seven miles to two miles southeast of Lawrence; July 14, 1948; 507–509.
Colinus virginianus
L480725–3–6; four miles south of Lawrence; July 25, 1948; 510.
Molothrus ater
L470729–3; five miles north, one mile east of Lawrence; July 29, 1947; 511–514, 519.
F471024–3; two miles south, one-half mile east of Lawrence; October 24, 1947; 515–518.
Passer domesticus
L470802–1; University of Kansas Campus, Lawrence; August 2, 1947; 31–48, 60–63, 520, 521.
L470823–3; University of Kansas Campus, Lawrence; August 23, 1947; 67, 68, 105, 522–533.
L470921–1; University of Kansas Campus, Lawrence; September 21, 1947; 78, 79, 677.
F471005–8; University of Kansas Campus, Lawrence; October 5, 1947; 27, 28, 534, 535.
RL480714–10; University of Kansas Campus, Lawrence; July 14, 1948; 75, 76.
L480715–1; July 15, 1948; 536, 537.
RL490620–1; University of Kansas Campus, Lawrence; June 20, 1949; 676.
Quiscalus quiscula
RL490614–2; eight miles south of Lawrence; June 14, 1949; 154, 538, 539.
RL490619–4; two miles west of Lawrence; June 19, 1949; 540–543.
Rallus
RL490623–3; two miles south of Lawrence; June 23, 1949; 544–546.
Richmondena cardinalis
K471017–4; Lawrence, October 17, 1947; 547–552.
Sialia sialis
L470729–2; five miles north, one mile east of Lawrence; July 29, 1947; 553–554.
Spiza americana
L470707–3; three miles north, one mile east of Lawrence; July 7, 1947; 555–556.
RL480714–6; seven miles to two miles southeast of Lawrence; July 14, 1948; 155, 557–562.
RL480719–3; three miles north of Lawrence; July 19, 1948; 728.
Sturnella magna
F471024–4; three miles south, one-half mile east of Lawrence; October 24, 1947; 563–567.
Sturnella neglecta
F471105–3; two miles south, one and one-half miles west of Lawrence; November 5, 1947; 568–569.
Sturnus vulgaris
RL490614–3; eight miles south of Lawrence; June 14, 1949; 570.
Troglodytes aedon
L470803–4; University of Kansas Campus, Lawrence; August 3, 1947; 571.
Turdus migratorius
L470820–1; University of Kansas Campus, Lawrence; August 20, 1947; 90–92, 94, 95, 98, 99, 100, 572–582.

L470921–2; University of Kansas Campus, Lawrence; September 21, 1947; 131, 132, 583, 584.

Tyrannus tyrannus

L470803–2; University of Kansas Campus, Lawrence; August 3, 1947; 88, 93.

Zenaidura macroura

F470817–1; three miles north, one mile east of Lawrence; August 17, 1947; 585.

L470928–4; three miles southeast of Lawrence; September 28, 1947; 586–590.

L480725–7–21; four miles south of Lawrence; July 25, 1948; 152, 591–597.

Mammals:

Canis familiaris

L470802–2; Lawrence; August 2, 1947; 84–86, 102, 598–602, 736.

Microtus ochrogaster

K471024–1; two miles south, one-half mile east of Lawrence; October 24, 1947; 603.

F471025–1; two miles south, one-half mile east of Lawrence; October 25, 1947; 604.

Sigmodon hispidus

F470827–11, 12; University of Kansas Campus, Lawrence; August 27, 1947; 605–615, 119.

F470827–11, Lawrence; August 28, 1947; 607–614.

K471025–10; two miles south, one-half mile east of Lawrence; October 25, 1947; 127, 138, 144, 150, 615–666.

RL481015–2, 3; Lawrence; October 15, 1948; 107, 11.

Sylvilagus floridanus

RL490621–2; Lawrence; June 21, 1949; 667.

RL490710–1; five miles south of Clinton; July 10, 1949; 668.

RL490714–1–5; three miles south, one mile east of Lawrence; July 14, 1949; 669.

RL490716–2; three miles south of Baldwin; July 16, 1949; 153, 162, 670.

Leavenworth County:

Turtle:

Terrapene ornata

RL490702–3; three and one-half miles east, three and one-half miles north of Lawrence; July 2, 1949; 391, 392.

Mammal:

Neotoma floridana

RL490702–1; three and one-half miles east, three and one-half miles north of Lawrence; July 2, 1949; 388, 694–724, 2002.

Logan County:

Bird:

Empidonax

RL490703–1, 2; one and one-half miles northeast of McAllaster; July 3, 1949; 725.

Montgomery County:

Bird:

Passer domesticus

F470911–31; Coffeyville, September 11, 1947; 726, 727.

Shawnee County:

Mammal:

Sylvilagus floridanus

RL480826–14; three miles west of Topeka; August 26, 1948; 345, 347, 349–352.

OKLAHOMA:

Delaware County:

Mammal:

Sigmodon hispidus

F470911–2; four miles northwest of Grove; September 11, 1947; 741.

One adult of *T. lipovskyana* was collected four miles south of Lawrence, Douglas County, Kansas, July 8, 1950. It was taken from a ridge in a swampy area along the Wakarusa River by the floatation method used to collect adults of *T. alfreddugèsi*.

TABLE I

LARVAL CHARACTERISTICS AND MEASUREMENTS

	multi-setosa	*batatas*		*belkini*	*splendens*				*alfreddugèsi*		*lipovs-kyana*	*tropica*
Source of Material	*	*	Kans.	Calif.	*	Mo.	Ark.	Tex.	*	Kans.	Kans.	*
Number of dorsal setae.	50–54	32–36	36–38	22	26(24)	24–28	24–26	24–26	22	22	22	22
Number of ventral setae.	42–46	22	24	14	16	16–17	16	16	14	14	14	14
Number of branches of palpal seta:												
Coxal	6–7	8	6–7	6	6–7	6–8	6–7	5–7	4–7	4–8	4–8	4–6
Femoral	4–6	4–6	5–8	5–6	4–6	3–4	2–4	0–3	4–6	2–5	4–7	4–5
Genual	1–2	1–3	1–3	1	0–3	0–2	0	0	0–3	0–3	1–4	0
Ventral tibial	2–4	2–5	1–5	3	3–4	3–5	3–4	2–4	1–4	1–5	0–4	0
Number of long nude hairs on tarsus III	3	3	3	0	1	1	1	1	1	1	1	1
Number of long nude hairs on tibia III	2	2	2	0	0	0	0	0	0	0	0	0
Standard measurements (ave. in microns):												
AW	79	64	63	74	78	83	92	100	81	77	86	79
PW	93	71	67	89	91	94	104	112	90	88	100	86
SB	39	27	27	36	44	43	47	50	43	43	44	45
ASB	23	21	22	22	22	24	25	25	23	23	26	21
PSB	29	25	22	29	32	28	31	31	31	26	27	31
AP	26	23	24	25	27	27	30	29	27	27	28	24
AM	38	29	31	26	37	33	35	36	33	28	36	35
AL	38	31	30	32	34	34	33	33	33	29	33	35
PL	48	43	40	39	48	47	47	47	45	40	50	48
S	52	52	56	57	51	52	53	52	50	49	50	48
DS	44	37	38	39	49	49	44	46	42	43	48	45
Number measured	(4)	(8)	(10)	(7)	(10)	(5)	(3)	(5)	(18)	(17)	(21)	(3)

*After Jenkins (1949).

TABLE II

ADULT CHARACTERISTICS AND MEASUREMENTS

	*batatas**	*splendens**	*lipovskyana*	*alfreddugèsi*
Length, mm	0.7–1.0	0.9–1.4	0.9–1.8	0.9–1.2
Length tarsus I, microns	190	167–183	220–277	167–217
Width of tarsus I, microns	67–71	76–107	109–135	71–107
Ratio length to width, tarsus I	2.67–2.83	2.03–2.83	1.5–2.7	1.7–2.6
Length tibia I, microns	131–138	119–155	142–178	121–171
Width tibia I, microns	64–67	74–107	99–128	71–107
Ratio tarsus I to tibia I	1.41–1.49	1.35–1.6	1.2–1.9	1.2–1.8
Length of palpal claws, microns	32–38	38–48	49–51	35–43
Ratio of claw to palpal tibia	0.5–0.66	0.52	0.6–0.7	0.5–0.6
Number of apical setae on tarsus	3.5	9–11	7–9	6–8
Tibial setae on tarsal base	1	2	(2)1†	(1–3)2
Length of scutum, microns	120–150	144–195	170–204	131–190
Width between pseudostigmatic setae, microns	38–47	57–69	60–71	44–52
Length of pseudostigmatic setae, microns	131–143	167–179	148–204	144–177
Ratio of diameter of eye to distance between pseudostigmatic setae	0.75–1.0	0.3–0.5	0.21–0.33	0.3–0.5
Length longest humeral setae, microns	31	31–43	43–57	30–48
Length longest posterior setae, microns	36–40	48–76	60–97	43–69
Ratio of length of humeral to posterior seta	0.7–0.8	0.54–0.7	0.45–0.7	0.5–0.8
Branches of pseudostigmatic setae	3	3–5	4–5	4–6

*After Jenkins (1949).

†Figures in parentheses are the exceptional numbers of setae at the tarsal base; figures not in parentheses are the usual numbers of setae at the tarsal base.

TABLE III

T. batatas Larvae from Kansas

Slide No.	No. of Branches of Palpal Setae:				Branches of pseudo-stigmatic setae	Standard Measurements										
	Coxal	Femoral	Genual	Ventral tibial		AW	PW	SB	ASB	PSB	AP	AM	AL	PL	S	DS
231	.....	6	1	1	5	65	71	30	21	21	23	33	31	42	55	33
232	6	8	3	2	.....	61	65	25	21	19	23	30	31	43	55	41
233	.....	.....	.....	.....	.....	59	65	26	21	19	19	.....	29	35	.....	41
234	.....	5	2	5	.....	60	63	24	21	19	23	30	31	43	55	41
235	7	6	2	3	.....	71	75	30	26	23	23	30	30	39	.....	38
236	7	5	2	2	.....	.....	.....	.....	.....	.....	25	.....	28	38	.....	39
237	.....	7	3	3	6	60	63	26	21	23	26	30	28	39	57	40
238	.....	.....	.....	.....	.....	64	63	25	21	20	25	29	30	39	.....	36
241	.....	7	2	3	.....	68	73	29	23	24	24	.....	31	43	.....	41
259	8	7	.....	2	3	62	68	28	23	25	27	32	28	41	60	41
Average of standard measurements						63	67	27	22	22	24	31	30	40	56	39

TABLE IV

T. belkini Larvae from Los Angeles County, California

Slide No.	Branches of Palpal Setae:				Branches of pseudo-stigmatic setae	Standard Measurements										
	Coxal	Femoral	Genual	Ventral tibial		AW	PW	SB	ASB	PSB	AP	AM	AL	PL	S	DS
2045	6	6	1	3	11	70	83	34	22	28	24	28	31	38	58	35
2046	6	6	1	3	11	75	94	40	23	29	28	26	31	38	57	39
2047	6	5	1	3	12	71	87	36	21	31	23	26	33	41	57	41
2051	6	5	1	3	12	71	88	33	21	31	26	26	31	39	54	38
2054	.....	.....	1	3	.....	75	88	40	22	28	27	26	31	38	.....	40
2055	.....	.....	1	3	12	75	87	35	21	33	25	.....	31	37	60	40
2056	6	.....	1	3	.....	80	97	35	23	26	25	.....	34	41	.....	39
Average of standard measurement						74	89	36	22	29	25	26	32	39	57	39

TABLE V

T. splendens LARVAE

Slide No.	Date collected	State collected	No. of Branches of Palpal Setae: Coxal	Femoral	Genual	Ventral tibial	Branches of pseudo-sitgmatic setae	Standard Measurements AW	PW	SB	ASB	PSB	AP	AM	AL	PL	S	DS
492	Sept. 5, '47	Missouri	8	.....	1	4	5	82	95	44	25	30	28	34	33	47	....	46
493	Sept. 5, '47	Missouri	6	4	2	4	6	82	90	42	25	29	28	34	31	46	51	50
495	Sept. 5, '47	Missouri	7	.....	1	3	5	83	94	43	24	28	28	35	35	50	....	53
498	Sept. 5, '47	Missouri	6	.....	0	4	8	85	95	45	25	27	25	32	31	48	53	47
499	Sept. 5, '47	Missouri	.....	3	0	5	.....	82	95	43	23	28	24	32	30	45	....	50
Average standard of measurements								83	94	43	24	28	27	33	34	47	52	49
421	March 26, '48	Texas	9	1	0	2	.....	102	112	52	24	29	29	39	36	45	41	48
422	March 26, '48	Texas	8	1	0	3	6	94	109	47	26	30	31	36	33	43	57	43
423	March 26, '48	Texas	7	2	0	2	6	100	112	48	27	32	28	38	34	47	55	43
425	March 26, '48	Texas	7	0	0	2	6	107	117	58	26	33	30	33	32	51	53	48
428	March 26, '48	Texas	8	0	0	3	5	95	111	47	23	31	28	37	32	48	55	46
Average of standard measurements								100	112	50	25	31	29	37	33	47	52	46
415	March 27, '48	Arkansas	6	4	1	4	8	87	100	50	28	28	28	33	31	45	53	44

TABLE VI

T. alfreddugèsi LARVAE FROM KANSAS

Slide No.	County collected	No. of Branches of Palpal Setae:				Branches of pseudo-stigmatic setae	Standard Measurements										
		Coxal	Femoral	Genual	Ventral tibial		AW	PW	SB	ASB	PSB	AP	AM	AL	PL	S	DS
22	Barber	5	5	1	3	.....	77	90	41	26	26	23	....	27	41	48	39
5	Cheyenne	6	4	0	3	5	82	94	43	23	26	28	....	28	39	47	37
11	Douglas	7	4	1	2	7	80	92	41	24	28	28	30	31	41	50	39
14	Douglas	5	4	0	2	5	74	85	43	22	22	27	26	28	38	45	43
37	Douglas	7	3	0	4	7	73	82	41	21	26	23	25	30	38	44	36
70	Douglas	5	4	1	2	8	68	80	36	21	25	23	23	26	40	....	33
25	Greenwood	7	6	1	3	.....	74	94	43	23	31	27	31	29	41	53	35
23	Miami	5	5	2	4	.....	79	87	43	24	26	27	26	28	38	47	37
3	Seward	6	4	1	4	8	80	87	45	24	22	27	25	28	38	44	36
243	Seward	.....	4	1	4	.....	77	80	47	24	24	28	31	28	44	53	48
326	Seward	4	4	0	5	.....	74	87	41	27	26	23	28	30	38	....	36
24	Shawnee	6	4	0	2	.....	90	103	49	23	25	27	28	29	41	51	40
270	Wallace	5	2	0	3	6	78	88	43	23	26	28	27	30	41	48	43
277	Wallace	6	.....	0	1	7	77	81	43	23	26	26	27	27	43	47	41
368	Wallace	5	4	0	1	5	71	79	41	22	24	28	28	32	41	47	43
Average of standard measurements							76	87	43	23	26	26	27	28	40	48	39

TABLE VII

MEASUREMENTS OF EIGHT NYMPHS OF *T. alfreddugèsi* FROM LAWRENCE, KANSAS

Slide Number	406	407	451	452	453	455	456	457	Average
Length, mm	0.5	0.4	0.4	0.5	0.5	0.4	0.4	0.5	0.45
Length tarsus I, microns	95	105	88	105	116	95	93	97	99
Width tarsus I, microns	58	56	58	60	56	60	58	60	58
Ratio length to width, tarsus I	0.6	0.5	0.6	0.5	0.5	0.6	0.6	0.5	0.55
Length tibia I, microns	77	75	68	80	88	68	65	77	75
Width tibia I, microns	63	61	58	65	63	58	53	60	60
Ratio tarsus I to tibia I	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.7
Length of palpal claw, microns	23	26	28	29	27	26	29	27	27
Ratio of claw to palpal tibia	0.7	0.6	0.8	0.7	0.7	0.7	0.7	0.7	0.7
Number of apical setae on tarsus	5	5	5	5	5	5	5	5	5
Tibial setae at tarsal base	1	1	1	1	1	1	1	1	1
Length of scutum, microns	90	83	85	95	95	.....	77	.....	88
Width between pseudostigmatic setae, microns	33	39	39	36	34	36	33	35	36
Length of pseudostigmatic setae, microns	104	.....	107	.....	99	99	99	99	101
Ratio of diameter of eye to distance between pseudostigmatic setae	0.3	0.3	.....	0.3	0.3	0.3	.....	0.3	0.3
Length longest humeral setae, microns	25	26	27	28	25	25	25	26	26
Length longest posterior setae, microns	47	42	43	50	50	43	43	42	45
Ratio humeral to posterior seta	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.6	0.5
Branches of pseudostigmatic setae	4	4	5	5	4	4	6	4	4–6

TABLE VIII

T. alfreddugèsi ADULTS FROM KANSAS

Slide Number	470	471	472	473	474	475	476	477	478	479	Average
Length, mm	1.2	.....	.....	.....	.....	.....	0.8	1.2	.....	.....	1.1
Length tarsus I, microns	192	206	192	178	199	213	192	170	178	185	191
Width tarsus I, microns	107	107	99	92	99	92	99	92	99	99	99
Ratio length to width, tarsus I	1.8	2.2	1.9	1.8	2.0	2.3	1.9	1.8	1.7	1.8	1.9
Length tibia I, microns	142	156	135	128	135	156	142	121	128	142	139
Width tibia I, microns	99	99	99	92	107	99	99	78	85	92	95
Ratio tarsus I to tibia I	1.3	1.3	1.4	1.3	1.4	1.3	1.4	1.4	1.3	1.8	1.4
Length of palpal claw, microns	37	.....	37	36	41	43	43	41	39	40	40
Ratio of claw to palpal tibia	0.58	.....	0.6	0.58	0.6	0.59	0.6	0.6	0.6	0.6	0.59
Number of apical setae on tarsus	7	8	7	7	7	.....	7	.....	6	6	6–8
Tibial setae at tarsal base	2	.....	2	2	2	2	2	1	1	3	1–3
Length of scutum, microns	145	162	146	150	162	179	146	145	131	145	151
Width between pseudostigmatic setae, microns	49	51	45	48	50	52	50	45	44	46	48
Length of pseudostigmatic setae, microns	.....	174	146	.....	153	163	.....	.....	149	144	155
Ratio of diameter of eye to distance between pesudostigmatic setae	0.3	0.3	0.3	0.3	0.3	.....	0.3	0.3	0.3	0.3	0.3
Length longest humeral setae, microns	31	34	38	36	39	44	37	37	36	38	37
Length longest posterior setae, microns	57	53	50	50	53	55	51	60	43	58	53
Ratio humeral to posterior seta	0.53	0.6	0.76	0.7	0.7	0.8	0.7	0.6	0.8	0.6	0.68
Branches of pseudostigmatic setae	4	5	5	.....	4	5	.....	.....	4	4	4–5
Sex	F	F	M	M	.....	F	M	.....	.....	M	

TABLE IX

LIFE CYCLE OF *T. alfreddugèsi*

MAJOR STAGES	INTERVENING STAGES	CHARACTERISTIC FEATURES	DURATION (days)*
Egg		Spherical, laïd singly.	15–20 (minimum 13)
	Deutovum	Quiescent, within broken egg shell, unsegmented appendages.	
Larva		Active, six segmented legs.	Up to 24 before feeding (over 30)
			1–4 on host (1–48)
			1–8 after leaving host (average 2)
	Prenympha	Quiescent, within dead larval integument.	9–10 (about 6)
Nymph		Active with eight legs, 2 pairs of genital suckers.	12–32 (minimum 7)
	Preadult	Quiescent, within nymphal integument.	5–10 (minimum 7)
Adult		Active, with eight legs, three pairs of genital suckers.	Up to 52 (over 20 months)
			Eggs laid within 14 (12)

*Figures in parentheses are from Jenkins (1947, 1948).

TABLE X

T. lipovskyana LARVAE FROM KANSAS

Slide No.		County collected	Branches of Palpal Setae				Branches of pseudo-stigmatic setae	Standard Measurements										
			Coxal	Femoral	Genual	Ventral tibial		AW	PW	SB	ASB	PSB	AP	AM	AL	PL	S	DS
308		Cheyenne	7		2	3		83	102	44	25	25	24		34	53		
310		Cheyenne	5		1	0		88	104	43	27	28	28	36	36	53		
15		Douglas	5	4	2	4	6	92	105	48	24	27	31	32	31	43	48	43
100		Douglas	7	7	1	3	7	83	95	43	24	27	28			50		50
105		Douglas	5		2	3	7	83	95	43	25	26	25	36	33	51		51
394	Paratype	Douglas					5	75	87	41	21	26	23	33	28	53	48	48
395	Paratype	Douglas	5	7	1	1	9	85	97	43	26	25	27	34	34	48	52	48
396	Paratype	Douglas	4	7	2	3	5	82	94	43	25	27	27		35	47	47	47
397	Paratype	Douglas			2	2	5	75	87	41	25	27	25	36	36	53	50	48
398	Paratype	Douglas		5	1	3	6	95	102	48	25	26	28	36	33	51	50	46
399	Paratype	Douglas	6	5	2	3		82	97	43	23	28	27	34	33	48	50	47
400	Paratype	Douglas			2		7	83	102	43	25	24	31	37	31	49		48
401	Paratype	Douglas			1			83	97	45	26	27	28	34	31	50		51
402	Paratype	Douglas			1	1		83	94	41	23	27	28		31	57		
403	Paratype	Douglas	7		3	2		85	92	40	25	25	26	36	31	50		45
404	Holotype	Douglas	5	5	2	3	5	92	105	48	24	27	31	32	31	43	48	43
388		Leavenworth	4	7	1	1	8	94	109	46	26	28	30	36	33	50	51	45
391		Leavenworth	5	5	2	3	7	92	105	49	38	27	31	43	36	54	55	50
360		Miami		4	4	1	6	88	99	46	28	26	29	37	36	52	53	50
349		Shawnee	4		2	2	9	95	121	46	26	28	28	36	33	50		48
350		Shawnee	8	7	2	2	9	94	109	43	24	27	30	37	33	48	50	45
Average of standard measurements								86	100	44	26	27	28	36	33	50	50	48

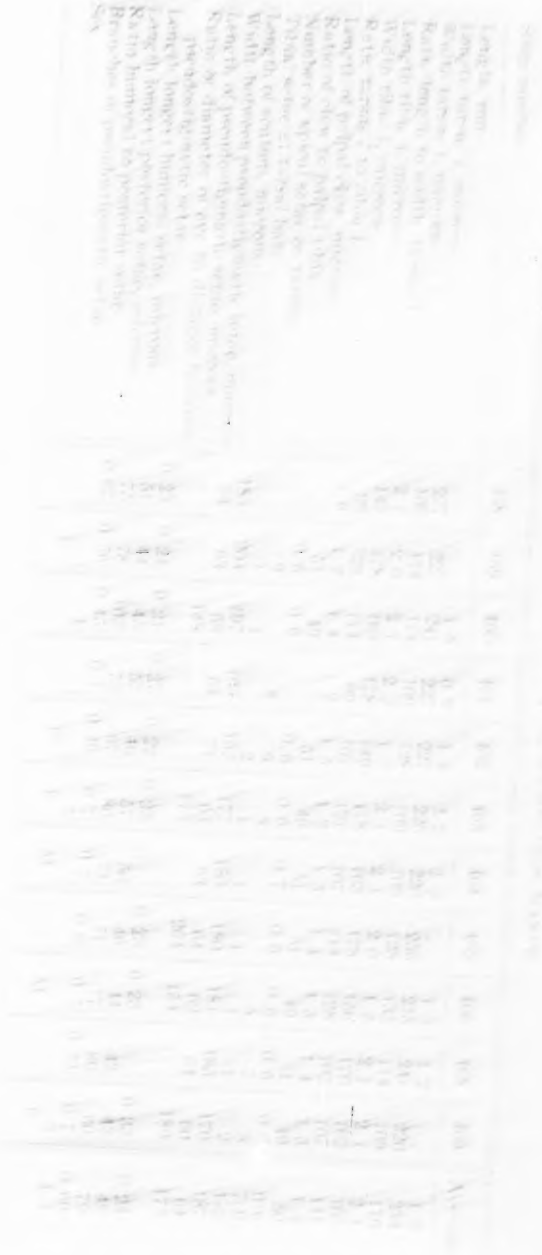


TABLE XI

T. lipovskyana NYMPHS FROM LAWRENCE, KANSAS

Slide Number	454	742	743	Average
Length, mm	0.81	0.85	0.83	0.83
Length tarsus I, microns	136	.....	136	136
Width tarsus I, microns	70	.....	63	66
Ratio length to width, tarsus I	0.51	.....	0.46	0.49
Length tibia I, microns	94	.....	.....	94
Width tibia I, microns	75	.....	.....	75
Ratio tarsus I to tibia I	0.69	.....	.....	0.69
Length of palpal claw, microns	34	39	31	35
Ratio of claw to palpal tibia	0.6	0.7	0.7	0.6
Number of apical setae on tarsus	5	5	.....	5
Tibial setae at tarsal base	1	.....	.....	1
Length of scutum, microns	158	119	114	130
Width between pseudostigmatic setae, microns	46	48	.....	47
Length of pseudostigmatic setae, microns	142	.....	131	137
Ratio of diameter of eye to distance between pseudostigmatic setae	0.3	.....	.....	0.3
Length longest humeral setae, microns	36	37	32	35
Length longest posterior setae, microns	62	.....	58	60
Ratio humeral to posterior seta	0.58	.....	0.56	0.57
Branches of pseudostigmatic setae	5	.....	5	5

LITERATURE CITED

Brennan, J. M., and **Wharton, G. W.** 1950. Studies on North American chiggers. No. 3. The subgenus Neotrombicula. Amer. Midl. Nat., 44(1): 153–197, 4 pls., 8 figs., 5 maps.

Cockings, K. L. 1948. Successful methods of trapping *Trombicula* (Acarina) with notes on rearing *T. deliensis* Walch. Bull. Ent. Res., 39: 281–296, 5 figs.

Ewing, H. E. 1921. Studies on the biology and control of chiggers. U. S. Dept. Agric. Bull. 986: 1–19, 4 figs.

1938a. The scientific name of the common North American chigger preoccupied. Proc. Helm. Soc. Washington, 5(1): 26–27.

1938b. A key to the genera of chiggers (mite larvae of the subfamily Trombiculinae) with descriptions of new genera and species. Jour. Washington Acad. Sci., 28(6): 288–295, 1 fig.

1943. The American chiggers (larvae of Trombiculinae) of the genus Acariscus, new genus. Proc. Ent. Soc. Washington, 45(3): 57–66, 1 fig.

Fuller, H. S. 1949. The mite larvae of the family Trombiculidae in the Oudemans Collection: Taxonomy and medical importance. Zool. Meded., Leiden, (In press).

Jenkins, D. W. 1947. The ecology and laboratory rearing of chiggers affecting men in the United States (Acarina, Trombiculidae). Ann. Ent. Soc. Amer., 40(1): 56–68, 1 fig., 1 tab.

1948. Trombiculid mites affecting man. I. Bionomics in relation to epidemiology in the United States. Amer. Jour. Hyg., 48: 22–35, 7 figs.

1949. Trombiculid mites affecting man. IV. Revision of *Eutrombicula* in the American Hemisphere. Ann. Ent. Soc. Amer., 43(3): 289–318, 3 pls., 5 tabs.

Michener, C. D. 1946a. Taxonomic and bionomic notes on some Panamanian chiggers (Acarina, Trombiculinae). Ann. Ent. Soc. Amer., 39: 411–417, 6 figs., 1 tab.

1946b. Observations on the habits and life history of a chigger mite, *Eutrombicula babatas*. (Acarina: Trombiculinae). Ann. Ent. Soc. Amer., 39: 101–118, 5 pls., 1 tab.

Oudemans, A. C. 1910. Acarologische aanteckeningen. Ent. Ber., 3(54): 83–90.

TABLE XII

MEASUREMENTS OF ELEVEN ADULTS OF *T. lipovskyana* FROM KANSAS

Slide number	458	459	460	461	462	463	464	465	466	468	469	Average
Length, mm			1.8	0.9	1.8	1.2	1.2		1.3	1.2		1.3
Length tarsus I, microns	277	227	241	227	227	220	220	256	213	241	220	234
Width tarsus I, microns	109	114	114	109	128	109	109	128	135	114	109	116
Ratio length to width, tarsus I	2.7	2.0	2.1	2.2	1.7	2.1	2.1	2.0	1.5	2.1	2.1	2.1
Length tibia I, microns	142	178	163	178	149	178	163	178	156	170	162	165
Width tibia I, microns	99	121	114	99	107	121	107	114	128	107	107	111
Ratio tarsus I to tibia I	1.9	1.2	1.4	1.2	1.5	1.2	1.3	1.4	1.3	1.4	1.3	1.4
Length of palpal claw, microns		51	49		51	49	51	51	49	51	49	50
Ratio of claw to palpal tibia		0.6	0.6		0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.6
Number of apical setae on tarsus		9		8	9	8			8	7	8	7–9
Tibial setae at tarsal base		1	1		2	1	1	1	1	1	2	1–2
Length of scutum, microns	185	204	197	199	197	177	185	180	181	185	170	187
Width between pseudostigmatic setae, microns	64	63	68	63	71	63	63	64	62	64	60	64
Length of pseudostigmatic setae, microns			148			175		204	154		186	173
Ratio of diameter of eye to distance between pseudostigmatic setae	0.23	0.24	0.21	0.27	0.22	0.23		0.23	0.23		0.33	0.24
Length longest humeral setae, microns	51	44	45	57	46	57	50	46	44	43	43	48
Length longest posterior setae, microns	75	78	102	75	97	80	71	71	77	80	60	79
Ratio humeral to posterior setae	0.67	0.56	0.45	0.7	0.46	0.7	0.7	0.6	0.5	0.53	0.7	0.60
Branches of pseudostigmatic setae			4			5					5	4–5
Sex		F			F	F	M		M		F	

TABLE XI

T. lipovskyana NYMPHS FROM LAWRENCE, KANSAS

Slide Number	454	742	743	Average
Length, mm	0.81	0.85	0.83	0.83
Length tarsus I, microns	136	.....	136	136
Width tarsus I, microns	70	.....	63	66
Ratio length to width, tarsus I	0.51	.....	0.46	0.49
Length tibia I, microns	94	.....	.....	94
Width tibia I, microns	75	.....	.....	75
Ratio tarsus I to tibia I	0.69	.....	.....	0.69
Length of palpal claw, microns	34	39	31	35
Ratio of claw to palpal tibia	0.6	0.7	0.7	0.6
Number of apical setae on tarsus	5	5	.....	5
Tibial setae at tarsal base	1	.....	.....	1
Length of scutum, microns	158	119	114	130
Width between pseudostigmatic setae, microns	46	48	.....	47
Length of pseudostigmatic setae, microns	142	.....	131	137
Ratio of diameter of eye to distance between pseudostigmatic setae	0.3	.....	.....	0.3
Length longest humeral setae, microns	36	37	32	35
Length longest posterior setae, microns	62	.....	58	60
Ratio humeral to posterior seta	0.58	.....	0.56	0.57
Branches of pseudostigmatic setae	5	.....	5	5

LITERATURE CITED

Brennan, J. M., and **Wharton, G. W.** 1950. Studies on North American chiggers. No. 3. The subgenus Neotrombicula. Amer. Midl. Nat., 44(1): 153–197, 4 pls., 8 figs., 5 maps.

Cockings, K. L. 1948. Successful methods of trapping *Trombicula* (Acarina) with notes on rearing *T. deliensis* Walch. Bull. Ent. Res., 39: 281–296, 5 figs.

Ewing, H. E. 1921. Studies on the biology and control of chiggers. U. S. Dept. Agric. Bull. 986: 1–19, 4 figs.

1938a. The scientific name of the common North American chigger preoccupied. Proc. Helm. Soc. Washington, 5(1): 26–27.

1938b. A key to the genera of chiggers (mite larvae of the subfamily Trombiculinae) with descriptions of new genera and species. Jour. Washington Acad. Sci., 28(6): 288–295, 1 fig.

1943. The American chiggers (larvae of Trombiculinae) of the genus Acariscus, new genus. Proc. Ent. Soc. Washington, 45(3): 57–66, 1 fig.

Fuller, H. S. 1949. The mite larvae of the family Trombiculidae in the Oudemans Collection: Taxonomy and medical importance. Zool. Meded., Leiden, (In press).

Jenkins, D. W. 1947. The ecology and laboratory rearing of chiggers affecting men in the United States (Acarina, Trombiculidae). Ann. Ent. Soc. Amer., 40(1): 56–68, 1 fig., 1 tab.

1948. Trombiculid mites affecting man. I. Bionomics in relation to epidemiology in the United States. Amer. Jour. Hyg., 48: 22–35, 7 figs.

1949. Trombiculid mites affecting man. IV. Revision of *Eutrombicula* in the American Hemisphere. Ann. Ent. Soc. Amer., 43(3): 289–318, 3 pls., 5 tabs.

Michener, C. D. 1946a. Taxonomic and bionomic notes on some Panamanian chiggers (Acarina, Trombiculinae). Ann. Ent. Soc. Amer., 39: 411–417, 6 figs., 1 tab.

1946b. Observations on the habits and life history of a chigger mite, *Eutrombicula babatas*. (Acarina: Trombiculinae). Ann. Ent. Soc. Amer., 39: 101–118, 5 pls., 1 tab.

Oudemans, A. C. 1910. Acarologische aanteckeningen. Ent. Ber., 3(54): 83–90.

THE DEVELOPMENT AND DIFFERENTIATION OF ARTHROPOD PROCUTICLE: STAINING

LEO SCHATZ

Division of Entomology and Economic Zoology
University Farm, St. Paul 1, Minnesota

INTRODUCTION

The recent book by Richards (1951) plus current research, suggests that the time is now ripe for reclassifying the terminology relating to differentiation of the subdivisions of the cuticle of insects. In addition, histological studies have not kept pace with the more recent chemical and physical studies (see Richards, 1951). The intent of this first paper is to reclassify the terms associated with subdivisions of the procuticle of hardened integuments.

Richards (1951) has proposed the term "procuticle" for the chitin-containing portion of the cuticle as opposed to the non-chitinous epicuticle. This set of terms has the advantage of being general enough to cover every known situation in the arthropod cuticle. The now out-dated paper of Richards and Anderson (1942) described three major subdivisions in the pronotal procuticle of the American cockroach (*Periplaneta americana* L.), a fact which has subsequently been overlooked. Their differentiation was based on light microscope observations and demonstrated (1) an outermost, hard, darkly-pigmented layer (exocuticle), (2) a pliable, colorless layer containing pore canals and lacking laminae ("outer layer of endocuticle") and (3) a pliable, colorless layer containing laminae and pore canals ("inner layer of endocuticle"). Of special interest is that their electron micrographs demonstrated a laminate structure as well as the presence of pore canals in all three layers. Wigglesworth (1948) divides the cuticle of the sternum of the adult mealworm (*Tenebrio molitor* L.) into (1) an "outer half of exocuticle," (2) an "inner half of ventral exocuticle" and (3) the endocuticle which is laminated and acidophil. In the seven day old pupa of the same species he notes that the exocuticle is quite thick and that inner and outer halves of the exocuticle may be distinguished. With Mallory's stain the inner half of the exocuticle stains red, the endocuticle stains blue.

The terminology used by the older workers which included such terms as secondary and primary cuticula used differently by different authors is confusing and cannot be translated into terms recognized by present-day workers without first reinvestigating the material they used.

MATERIALS AND METHODS

The developmental study was carried out on the nymphal abdominal cuticle of the Oriental cockroach (*Blatta orientalis* L.). Studies of fully developed material was carried out on the adults of the American cockroach (*Periplaneta americana* L.), the German cockroach (*Blatella*

germanica L.), the preying mantis (*Mantis religiosa* L.), a grasshopper (*Melanoplus bivitattus* Say), the "musk mare" (*Anisomorpha buprestoides* Stoll) (Phasmidae), and the common northern walking-stick (*Diapheromera femorata* Say).

Material was fixed mainly in cold Carnoy's 6–3–1, and hot Deitrich's fluid (60°C.) although some material was also fixed in Bouin's, alcoholic Bouin's, and strong Fleming's with acetic. The standard paraffin method was followed except that cedar oil was used in clearing from 95% ethyl alcohol, in order to avoid the possible hardening action of absolute alcohol. Material was infiltrated and embedded in 56–58°C. "Tissuemat" (rubber-paraffin) and sectioned at 4, 6 and 7 microns. Mallory's connective tissue stain,[1] iron hematoxylin, phosphotungstic hematoxylin, and Delafield's hematoxylin with erythrosin or eosin Y, and many other common stains were used. Unstained slides were used as checks.

DESCRIPTION OF HARDENED CUTICLE

The fully-developed cuticles of all the species listed above were stained with Mallory's stain as well as hematoxylin and the Millon's and ninhydrin reactions were performed, in order to determine whether some description for the procuticle would apply to all.

Exocuticle: The exocuticle usually appears as a non-staining, clear, amber-colored layer, usually lacking visible laminations and containing pore canals (which may or may not be visible). In some regions diffuse brown or black pigments are noted, as in the cuticle of cockroaches. In the light yellow areas of cockroach pronota, and large areas of the exocuticle of *M. religiosa* and *D. femorata* such diffuse pigments are lacking. (Interestingly enough, the pore canals penetrating the abdominal cuticle of *D. femorata* contain large black granules in their distal portions and one can imagine that these pore canals even penetrate the two epicuticular layers visible in paraffin sections.) The exocuticle is generally hard whether pigmented a light amber, brown, or black, and the rigidity appears to be a function of thickness, not the hardness of different regions. Thus, sclerotization (hardening) is not necessarily related to pigmentation. In fact, hardened regions are known in the tarsi of Orthoptera (Schatz, 1952) which are neither pigmented nor completely resistent to staining. The exocuticle is usually refractory to most histochemical tests, or such tests are masked by the pigments normally present.

Mesocuticle: The next inner layer is representative of the endocuticle by being soft, colorless, containing pore canals, and staining readily with such stains as acid fuchsin, iron hematoxylin, phosphotungstic hematoxylin and others of a similar nature. This layer resembles the exocuticle in that the laminations are not generally visible, and appears homogeneous (light microscope). This layer produces intensely positive Millon's reaction and ninhydrin tests.

The term *mesocuticle* is proposed for this layer in keeping with present anatomical usage (i.e., exo-, meso- and endo-).

[1]In Mallory's stain the acid fuchsin solution was pH 3.0 and the aniline blue-oxalic acid-orange G solution was pH 1.1.

Endocuticle: The endocuticle is a pliable, colorless, generally coarsely laminated layer which stains readily with such stains as the aniline blue of Mallory's stain, and light green. This layer is negative or very faintly positive to Millon's and ninhydrin reactions. Pore canals are present, but one is rarely able to trace them directly to the epidermal cells in fully-developed cuticles, except in some cases when the cuticle becomes slightly separated from the cells and strands can be seen extending across the space. There seems to be some reason for specifying an additional endocuticular layer which appears to lack pore canals ("inner endocuticle"—Dennell, 1946, 1947).

DEVELOPMENTAL STUDIES

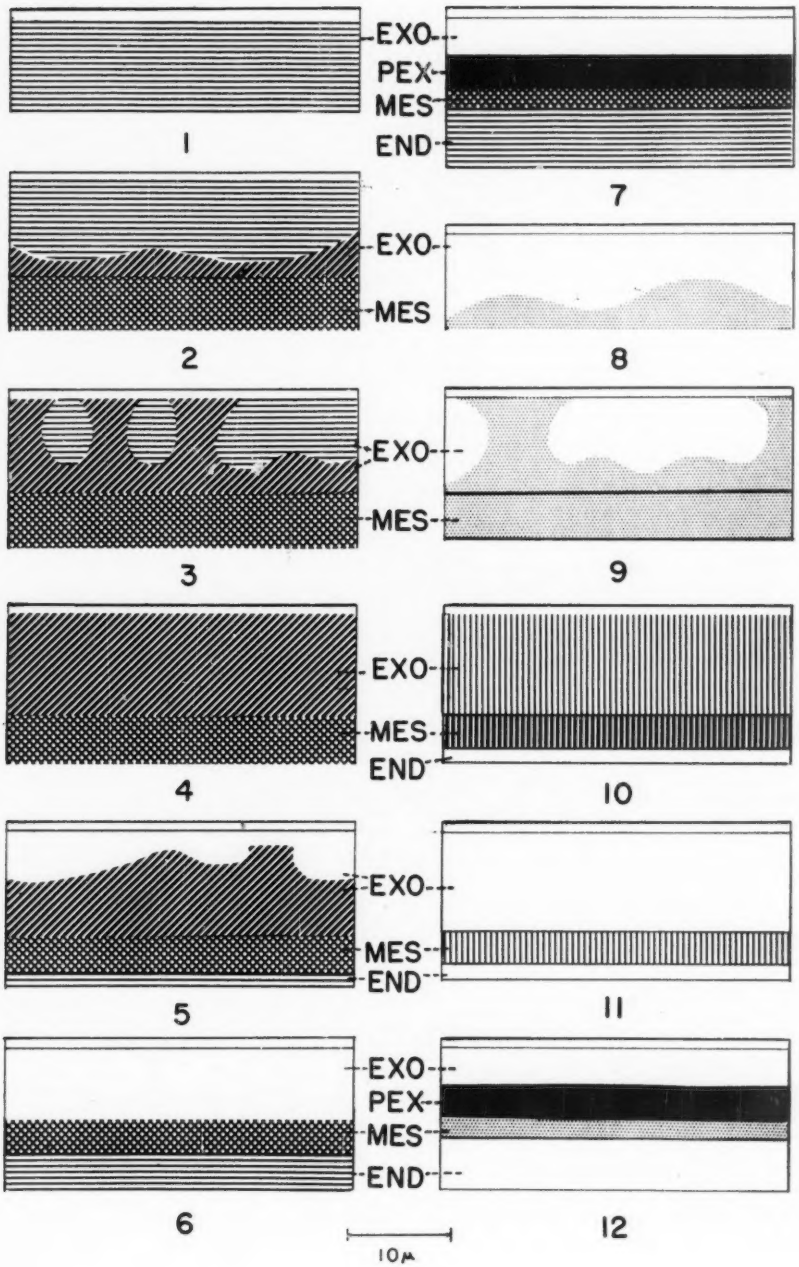
Developmental studies were carried out with teneral and fully-hardened abdominal cuticles of nymphs of *B. orientalis* during the various stages of hardening and pigment formation. Mallory's connective tissue stain and phosphotungstic hematoxylin produced the most interesting results, and these will be described in detail.

Mallory's Connective Tissue Stain: Nymphs of *B. orientalis* fixed immediately after or during a molt demonstrated a thin procuticle (fig. 1) which stained a uniform blue with Mallory's stain. This may well be called the "presumptive exocuticle" and is at least partly pre-exuvial in origin. During the formation of the pink-staining mesocuticle (fig. 2), there is an outward migration of material into the presumptive exocuticle which stains an intense red or magneta.[2] The migration of material continues (fig. 3) until all the blue-staining portion of the presumptive exocuticle has been changed into a red-staining area. At this time (fig. 4) the presumptive exocuticle begins to stain less intensely red, while the presumptive mesocuticle stains very intensely red. As the endocuticle begins to form (fig. 5) there is an inward migration of material, apparently from the epicuticle, which results in an amber-coloration in the previously colorless inner epicuticular layer as well as in a portion of the presumptive exocuticle. The overall effect of light red stain and amber coloration is an impure orange. Soon thereafter the red stain is no longer picked up by what is now fairly well formed exocuticle (fig. 6); simultaneously the endo-

[2]Intense Millon's reaction indicates that the primary diffusing substance contains or is a phenol or phenolic derivative. In addition, the acid fuchsin, hematoxylin staining seem to parallel positive Millon's reactions. (Ito, 1951b, has also noted this parallelism.)

EXPLANATION OF PLATE I

Differentiation of the abdominal procuticle of the Oriental Cockroach: FIGS. 1–7. Progressive differentiation exhibited with Mallory's connective tissue stain. FIGS. 8–12. Progressive differentiation exhibited with phosphotungstic hematoxylin. Figs. 7 and 12 represent fully-developed procuticles. END = endocuticle, EXO = exocuticle, MES = mesocuticle, and PEX = the inner region of the exocuticle containing dense black pigment. Horizontal lines represent blue staining with Mallory's stain; while cross-hatched lines represent red staining with Mallory's stain in the mesocuticle. Stippled areas represent diffuse staining with hematoxylin, while light and heavy vertical lines represent light and heavy staining of the pore canals with hematoxylin. Colorless areas represent unstained or amber-colored regions.


EXO
PEX
MES
END
1
7
EXO
MES
2
8
EXO
MES
3
9
EXO
MES
END
4
10
EXO
MES
END
5
11
EXO
PEX
MES
END
6
12
10μ

cuticle becomes thicker. Correlated to "tanning" of the exocuticle, the presumptive exocuticle shrinks to about 50–60% of its former thickness, while the presumptive mesocuticle shrinks to approximately 40% of its original thickness as determined by measurements made on paraffin-cut sections. In the fully-pigmented procuticle the inner 25–50% of the compact exocuticle becomes colored with a diffuse black pigment (fig. 7). The blue-staining endocuticle continues to become thicker for some time.

Thus the fully-hardened procuticle consists of (1) an outer, non-staining, hard layer lacking visible laminations, but containing an inner region with dense black pigmentation (in *B. orientalis* this layer is known as the exocuticle); (2) a median layer which is soft but fairly compact, without visible laminations, stains readily with acid fuchsin, for which the name *mesocuticle* has been proposed; and (3) the innermost, soft, blue-staining, laminated layer known as the endocuticle. Pore canals are present in all the layers with the possible exception of the last two or three innermost laminations of the endocuticle.

Phosphotungstic Hematoxylin: Staining the procuticle of *B. orientalis* nymphs with hematoxylin shows patterns similar to those noted above for the acid fuchsin of Mallory's stain. With phosphotungstic hematoxylin, the exact distribution of the stain becomes more evident. In the very early postmolt stage (fig. 8), a small irregular inner region of the presumptive exocuticle stains almost black. As the presumptive mesocuticle is deposited internally, material in the exocuticle appears to have diffused in several patterns, as far as the inner layer of epicuticle (fig. 9). The completely stained presumptive exocuticle shortly appears to pick up less stain. At this time the pore canals suddenly become visible because the stain is concentrated in or around them, rather than in the body of the exocuticle itself (fig. 10). The pore canals in the presumptive mesocuticle seem to have more stain concentrated within them, at the same time that one notices some shrinkage within this layer. The pore canals in the mesocuticle, especially along the inner border, appear to be much thicker. Whether this thickening is an optical phenomenon due to increased stainability, or whether shrinkage of the mesocuticle results in coiling of the pore canals with the resultant illusion of thickening, could not be determined by the methods used in this study. A small amount of endocuticle appears here (*ca.* 1 micron). In the next stage (fig. 11) the exocuticle has become mostly amber-colored with a very diffuse hematoxylin occasionally visible, but at the same time the inner layer of epicuticle is no longer as readily visible as previously. The pore canals of the presumptive mesocuticle stain much more lightly than previously. In the fully hardened and pigmented procuticle (fig. 12) the exocuticle has shrunken considerably (on the order of 50% of its former thickness) and possesses an outer amber-colored layer and an inner black pigment layer which makes up ¼ to ½ of the exocuticle. The mesocuticle has shrunken still further and picks up a light, diffuse stain with hematoxylin, while the inner border stains intensely. The endocuticle does not pick up any of the stain and is noticeably coarsely laminate (the laminations show up very nicely under the phase microscope).

DISCUSSION

The trends indicated by the staining patterns are in essential agreement with those postulated by Dennell (1947) in puparium formation by mature *Sarcophaga* larvae. He indicates that on hardening, a polyphenol passes into the cuticle and accumulates in the outer endocuticle (presumptive exocuticle ?). The polyphenol is oxidized to the ortho-quinone by an oxidase at the inner epicuticle. These ortho-quinones may be able to induce oxidation in the advancing polyphenol so that a wave of quinone formation moves inwards through the "presumptive exocuticle." The quinones combine with the protein present in the outer layer of cuticle ("tanning") producing the coloration along with the decrease in thickness of this layer to form what may be referred to as the exocuticle.

The present work demonstrates that on hardening of the cuticle a stainable material which is apparently bound or adsorbed on the chitin-protein complex, spreads outwards and that upon reaching its maximum extent at the inner epicuticular layer, another material is produced which diffuses internally. The result of what may be combination of diffusing substance or substances with the proteins that have stained previously, results in a loss of stainability by the presumptive exocuticle with the simultaneous production of an amber coloration ("tanning"). The suggestion is made that the loss in stainability may be due to "locking-in" of the reactive groups, either by a change in molecular configuration or by reaction with other groups or both, with a resultant change in iso-electric point.

Dennell (1947) finds that what is presumably the presumptive exocuticle of *Sarcophaga* larvae is 150 microns thick and that the exocuticle is 70 microns, which is a decrease in thickness of 53%. In the Oriental cockroach the presumptive exocuticle of the abdominal tergum is ca. 10 microns thick and the fully hardened and pigmented exocuticle is ca. 4.5–6.0 microns thick, a decrease of 40–55%. (Assuming that the mechanical factors in the two insects (*Sarcophaga* larvae and *B. orientalis* nymphs) are the same, the errors in measurement of thin cuticle may account for the discrepancy in the percentage figures, or it may be due to individual variations in the culture specimens.) The decrease in thickness of the presumptive mesocuticle in the Oriental cockroach is from ca. 4 microns to ca. 1.5–2.0 microns, which is in the range of 50–60%.

The papers by Ito (1951a) and Kuwana (1933, 1940) describe an outer layer in the procuticle of the larval silkworm which stains red with Mallory's stain, and in addition reacts strongly with Millon's reagent. They have termed this layer the "exocuticle" as opposed to the inner layer which stains blue with Mallory's stain, the "endocuticle." Bartlett (1949) points out that in the larval cuticle of the European corn borer (*Pyrausta nubilalis*) the exocuticle is limited to the head, mouthparts, restricted areas of the abdomen and thorax, and to placques surrounding the bases of setae, and is present as amber-colored non-staining regions. In addition he finds an external layer which stains red with Mallory's stain, and an inner layer which stains blue with the same stain. The present author has confirmed this

restriction of exocuticle in the larvae of *Heterocampa manteo* (Lepidoptera). Dennell (*loc. cit.*) has also noted the presence of an outer hardened and pigmented exocuticle in *Sarcophaga puparia*, and in addition a median layer which stains red with Mallory's stain and an inner layer which stains blue with the same stain. Wigglesworth (*loc. cit.*) has found a similar sort of differentiation in the procuticle of the pupa of *Tenebrio molitor*.

Clearly, the evidence is against our calling any outermost layer an exocuticle merely because it has been secreted pre-exuvially, or because it happens to be outermost.

Richards (1951) used the term exocuticle for any hardened (usually colored) procuticle subdivision but implied that further terminology might be required when the case of hardened but not darkened cuticles is studied. It seems to the present author that the recognition of exo-, meso- and endocuticle fractions fits known developmental histories and allows classifications of all insects and possibly arthropod procuticles. On this scheme, some procuticles would contain only endocuticle (certain soft membranes), some would contain endo- and mesocuticles (some intersegmental membranes), some would contain endo-, meso- and exocuticles (the usual sclerites), and in certain cases the procuticle may become completely modified into exocuticle after going through a developmental stage corresponding to mesocuticle (honey bee antennae). In connection with the development of honey bee antennae (Richards, 1952) it is interesting to note that the progression of diffusion is exactly the opposite to that described for the procuticle of the Oriental cockroach. However, the end result is the same in that the whole antenna (with the exception of the intra-antennal membranes and placoid sensillae) is converted into exocuticle, and even has an inner region containing a region of pigment which is added after the exocuticle has become amber-colored.

The recent paper by Blower (1951) describes the cuticles of two chilopods and two diplopods. In the chilopod *Lithobius forficatus* (L.) he presents a cuticular staining picture which is like that found in othropterous procuticles. He describes: (1) an outermost unstained layer ("exocuticle"), (2) a median layer which stains with acid fuchsin and iron hematoxylin ("basiphil zone beneath exocuticle") and (3) an innermost laminated layer which stains blue with Mallory's stain ("endocuticle"). The outer cuticles used in the study did not show as clear a differentiation as the one above. The possibility is present that his "papillate part of exocuticle," " 'intermediate sclerite' exocuticle" and "prismatic cone of exocuticle," among others, may all be the same as the mesocuticle of the present paper. Blower's suggestion that what he terms "prosclerotin" (presumably a precursor of "sclerotin") is responsible for the staining reaction of the fuchsinophile portion of the "exocuticle" certainly has credance, but is in need of further substantiation.[3]

Another paper by Ito (1951b) describes the formation of the pupal cuticle of *Bombyx mori*. The pupal procuticle first appears as a trans-

[3]The present work would suggest (see footnote 2) that the term "prosclerotin" may represent the phenol-containing material found in the mesocuticle.

parent thin layer which neither stains with hematoxylin nor produces positive phenol reactions (Millon's, diazo or argentaffin). Just before pupation the entire pupal procuticle stains with hematoxylin and reacts with phenolic reagents. After ecdysis, as hardening and amber coloration of the procuticle proceed (presumably in the outermost region) there is a loss in staining property as well as negative phenol tests. Ito diagrams the pupal cuticle as having a single-layered epicuticle, an outer amber-colored, non-staining, hard exocuticle (exo), a median layer which stains with hematoxylin and gives positive phenol tests (end_1) and an innermost layer which neither stains nor gives positive phenol tests (end_2).

The present author is of the opinion that the exocuticle should be more restrictively defined as: hard, refractory to staining and histochemical tests, and usually but not always containing variable amounts of pigments. The so-called "exocuticle" of lepidopterous (Ito, 1951a) and possibly other holometabolous larvae may actually be homologous to "presumptive exocuticle" or mesocuticle or both.

The reported presence or absence of pore canals depends more on visibility than on actual presence or absence of these structures and the use of pore canals as a diagnostic character should be checked by other means (e.g., electron microscopy or phase microscopy).

SUMMARY

The present paper outlines a scheme for the differentiation of the procuticle into three subdivisions (viz., exocuticle, mesocuticle, endocuticle) utilizing the hardened or fully-developed cuticles of three cockroaches, one grasshopper, two phasmids and one mantid, plus the additional evidence supplied by the developing cuticles of teneral nymphs of *Blatta orientalis* and of honey bee antennae. Restrictive definition of the exocuticle, plus the introduction of a new term (*mesocuticle*) fit into a scheme which will describe the procuticle of known insects and possibly other arthropods.

Three subdivisions of the hardened procuticle seem to be valid when the developmental phases are examined, since such studies indicate that the exocuticle, mesocuticle and endocuticle are secreted as sequential entities. Histochemical and microchemical methods of analysis are needed for further substantiation of the existence of the three layers outlined.

ACKNOWLEDGMENT

To Dr. A. Glenn Richards, University of Minnesota, not only for providing the materials used in this study, but for making available unpublished research, reviewing the manuscript and offering valuable criticism, the author wishes to express his sincere appreciation.

LITERATURE CITED

Bartlett, L. M. 1949. Histological studies of the larval European corn borer. Unpublished thesis, Cornell University, Ithaca, N. Y.

Blower, G. 1951. A comparative study of the Chilopod and Diplopod cuticle. Quart. J. Micro Science, 92: 141–161.

Dennell, R. 1946. A study of an insect cuticle: the larval cuticle of *Sarcophaga faculata* Pand. (Diptera). Proc. R. Soc. London, ser. B, 133: 348–373.

1947. A study of an insect cuticle: the formation of the puparium of *Sarcophaga falculata* Pand. (Diptera). Ibid., 134: 79–110.

Ito, T. 1951a. Studies on the integument of the silkworm, *Bombyx mori*. I. Histology and cytology of the integument during the moulting period. Bull. Sericult. Exp. Sta. (Tokyo), 13: 305–328.

1951b. II. Histology and cytology of the integument at the pupation period. Ibid., 13: 585–611.

Kuwana, Z. 1933. Notes on the growth of cuticle in the silkworm. Proc. Imp. Acad. Tokyo, 9: 280.

1940. Some histochemical characters of the cuticle of the larva of *Bombyx mori* L. Annot. Zool. Jap., 19: 309.

Richards, A. G. 1951. The Integument of Arthropods. University of Minnesota Press, Minneapolis, Minnesota.

1952. Studies in arthropod cuticle 8. The cuticle of honeybee antennae with special reference to the sense plates. Biol. Bull. (In press.)

and **T. F. Anderson.** 1942. Electron microscope studies of insect cuticle with a discussion of the application of electron optics to this problem. J. Morph., 71: 135–183.

Schatz, L. 1952. The finer structure of the tarsal integument of Orthoptera. Unpublished thesis. Cornell University, Ithaca, N. Y.

Wigglesworth, V. B. 1948. The structure and deposition of the cuticle in the adult mealworm, *Tenebrio molitor*. Quart. J. Micro. Sci., 89: 197–217.

PROBIT ANALYSIS: A STATISTICAL TREATMENT OF THE SIGMOID RESPONSE CURVE, by D. J. FINNEY. Second edition. xvi+318 pages. New York-London, Cambridge University Press. 1952. Price, $7.00.

The first edition of this book (1947) was widely used, and was sold out promptly. The second edition contains the material of the first, together with discussion of recent advances and references to new articles.

It deals with a specific branch of bioassay. The latter term is used to indicate evaluation of a reagent by its effect on biological organisms. The basic comparison is of concentrations needed to produce a given effect; if it requires twice as much of reagent A as of B, A is only half as good. Where the effect is not measured on a graded scale for each organism, but is only indicated by death or survival ("all-or-none" reaction), proportion or percentage of mortality must be used, and a number of organisms are needed for a single figure. This leads to studies of the dosage-mortality type. Finney's book deals with a treatment of the dosage-mortality curve in which percentages of mortality are converted to "probits" or standard deviation units, and concentration units are turned to logarithms. The curve then becomes fairly linear. This treatment has been successful and has found wide use.

The book discusses definitions, history of dosage-mortality studies, basic features of the probit method, and briefly mentions alternative methods. It then illustrates the fitting of the probit-log regression, estimation of median lethal dose (or dose fatal to 50%) and other measures of effect, and of standard errors for estimates. Special cases such as adjustments for natural mortality, more complex experiments, joint action of insecticides, and other applications, are discussed. The book closes with appendices on computational methods, mathematical derivations, a bibliography, and statistical reference tables.

This book is a complete treatment of the probit-log solution for the dosage-mortality curve. It is well illustrated with numerical examples, and does not seem hard to follow by anyone interested in techniques of toxicological experiments. It has already proved useful, and should be increasingly used.—F. M. WADLEY.

NOTICE TO MEMBERS AND CONTRIBUTORS

The Annals of the Entomological Society of America, published by the Society quarterly, includes the Proceedings of the Annual Meetings and such papers as may be selected by the Editorial Board.

Papers should ordinarily be submitted directly to the Editor. However, they may be submitted to any member of the Editorial Board, especially where such member is particularly qualified in the subject matter of the paper.

Any illustrated manuscripts submitted must be accompanied by finished illustrations which are ready for reproduction (or by engravings plus proof if the author prefers to have his own made). **The price of zinc cuts or half-tone engravings in excess of one page of cuts for each twelve pages of printed matter will be charged to the author at cost.** It is to be noted that text, tables, zinc cuts and half-tone engravings are all printed alike on one quality of paper at the standard 4¼ x 6¾ inch size. **If an author has tabular material or illustrations that require another size or a special paper, such is obtainable only by special arrangement with the editor and at the expense of the author.**

Acceptable style and format depends to some extent on the subject matter to be treated. Authors are referred to recent issues of the journal for the usual styles.

Since the Annals is not a copyrighted journal, permission to quote or to use illustrations is within the province of the author or authors.

Authors will be charged for reprints at cost. Orders should be placed at the time the proof is returned to the Editor.

Members failing to receive their numbers should present the complaint to the Managing Editor within four months from the date of the mailing of the issue. After that time the numbers will be furnished only at the regular published rate. Requests for membership should be sent to the Secretary, Dr. A. C. Hodson, University of Minnesota, St. Paul 1, Minnesota, and annual dues of members to Dr. S. W. Frost, Pennsylvania State College, State College, Pennsylvania.

SUBSCRIPTION RATES AND BACK NUMBERS

The regular subscription rate for the ANNALS is $6.00 (U. S. money) in the United States and all other countries.

Subscriptions from non-members, and orders for back numbers, are now being handled through the Columbus office. Letters should be addressed to Mrs. Helen S. Lanman, Dept. of Zoology and Entomology, The Ohio State University, Columbus 10, Ohio.

The stock of back numbers of the ANNALS is now in charge of The Spahr & Glenn Company, 50 East Broad Street, Columbus 15, Ohio, by whom all shipments will be made, but orders should be addressed to Mrs. Helen S. Lanman as above.

Back numbers are furnished at the following prices: Volumes 1 to 31, $4.00 per volume, $1.00 per issue; Volumes 32 to 38, $5.00 per volume, $1.25 per issue; Volumes 39 to 43, $6.00 per volume, $1.50 per issue.

THE THOMAS SAY FOUNDATION

Vol. I—*Sarcophaga and Allies of North America* . . . . . Price, $3.00
By J. M. ALDRICH

Vol. II—*Plecoptera or Stoneflies of North America* 5.00
By J. G. NEEDHAM and P. W. CLAASSEN

Vol. III—*Plecoptera Nymphs of North America* 4.00
By P. W. CLAASSEN

Vol. IV—*The Blowflies of North America* 6.50
By DAVID G. HALL

Members of the Entomological Society of America will receive a ten percent discount on volume IV, if the purchase is a personal one.

Send orders to J. J. DAVIS, Purdue University, Lafayette, Indiana.

Orders outside the United States, Canada, Mexico and U. S. Possessions, 50 cents extra per volume.

All accounts with the Entomological Society of America, or its Journal, "The Annals," owing by individuals or institutions without the United States should be paid by Postal Money Order or in American dollars.

CONTENTS OF THIS NUMBER

PAGE

FAIRCHILD, G. B., AND MARSHALL HERTIG—Notes on the *Phlebotomus* of Panama. IX. Descriptions of Seven New Species.. 505

GALINDO, PEDRO, STANLEY J. CARPENTER, AND HAROLD TRAPIDO—The Taxonomic Status of the *Aedes leucocelaenus* Complex with Description of Two New Forms (Diptera, Culicidae)..... 529

FLANDERS, STANLEY E.—Biological Observations on Parasites of the Black Scale..... 543

KAHN, NAWAB H.—Oviposition and Hatching in some Species of Tabanidae (Diptera)..... 550

CHAMBERLIN, RALPH V.—Some American Polydesmid Millipeds in the Collection of the Chicago Museum of Natural History..... 553

TSAO, CHING-HSI, AND A. GLENN RICHARDS—Studies on Arthropod Cuticle. IX. Quantitative Effects of Diet, Age, Temperature and Humidity on the Cuticles of Five Representative Species of Insects..... 585

JAMESON, E. W., JR.—*Euhaemogamasus keegani*, New Species, a Parasitic Mite from Western North America (Acarina: Laelaptidae, Haemogamasinae)..... 600

DALMAT, HERBERT T., AND COLVIN L. GIBSON—A Study of Flight Range and Longevity of Blackflies (Diptera, Simuliidae) Infected with *Onchocera volvulus*..... 605

STEPHEN L. WOOD—Observations on the Homologies of the Copulatory Apparatus in Male Coleoptera..... 613

HORSFALL, WILLIAM R., ROBERT C. MILES AND JOHN T. SOKATCH—Eggs of Floodwater Mosquitoes. I. Species of *Psorophora* (Diptera: Culicidae)..... 618

DECOURSEY, JOHN D., AND A. P. WEBSTER—A Method of Clearing the Chorion of *Aedes sollicitans* (Walker) Eggs and Preliminary Observations on Their Embryonic Development..... 625

GILBERT, EDWARD E.—The Homologies of the Male Genitalia of Rhynchophora and Allied Coleoptera..... 633

SUSSMAN, ALFRED S.—Studies of an Insect Mycosis. V. Color Changes Accompanying Parasitism in *Platysamia cecropia*..... 638

WOLFENBARGER, KEITH A.—Systematic and Biological Studies on North American Chiggers of the Genus Trombicula, Subgenus *Eutrombicula* (Acarina, Trombiculidae)..... 645

SCHATZ, LEO—The Development and Differentiation of Arthropod Procuticle: Staining..... 678

Errata..... 644

Book Notices.....542, 584, 604, 612, 617, 637, 686

Index to Volume 45..... 687

PRINTED IN THE UNITED STATES OF AMERICA
THE SPAHR & GLENN COMPANY, COLUMBUS, OHIO